THE BRITISH SOCIETY FOR THE PROMOTION OF VEGETABLE RESEARCH

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First Annual Report

1950

(OCT. 1949 - SEPT. 1950)

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NATIONAL VEGETABLE RESEARCH STATION

WELLESBOURNE - - WARWICK

1951

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GOVERNING MEMBERS OF THE SOCIETY

Appointed by the Minister of Agriculture and Fisheries :

Sir EDWARD J. SALISBURY, C.B.E., D.Sc., F.R.S., F.L.S., Royal Botanic Gardens, Kew.

Sir WILLIAM G. OGG, M.A., B.Sc., B.Sc.(Agric.), Ph.D., Rothamsted Experimental Station, Harpenden, Herts.

Dr. H. V. TAYLOR, C.B.E., A.R.C.S., V.M.H., Preston Grange, Barnet Road, Potters Bar, Middlesex.

Professor G. E. BLACKMAN, M.A., Department of Agriculture, University of Oxford.

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R. L. SCARLETT, Esq., O.B.E., Sweethope, Musselburgh, Midlothian.

Appointed by the Department of Scientific and Industrial Research :

Dr. R. G. TOMKINS, M.A., Ditton Laboratory, East Malling, Kent.

Appointed by the University of London :

Professor J. W. MUNRO, C.B.E., D.Sc., M.A., Zoology Department, Imperial College of Science and Technology, South Kensington, London, S.W.7.

Appointed by the University of Reading :

Professor R. H. STOUGHTON, D.Sc., The University, Reading.

Appointed by the University of Cambridge :

Professor F. T. BROOKS, C.B.E., M.A., LL.D., F.R.S., F.L.S. (*Chairman*), The Botany School, Cambridge.

Appointed by the University of Bristol :

Professor T. WALLACE, C.B.E., M.C., D.Sc., F.R.I.C., The Research Station, Long Ashton, Bristol.

Appointed by the University of Edinburgh :

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Appointed by the Royal Society :

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Appointed by the John Innes Horticultural Institution :

Dr. C. D. DARLINGTON, F.R.S., Bayfordbury, Herts.

Appointed by the National Farmers' Union :

E. H. GARDENER, Esq., Steinbrook, Kington Langley, Nr. Chippenham, Wilts.

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W. F. SWIFT, Esq., Avon Cottage, Fladbury, Pershore, Worcs.

J. LAITY, Esq., Polkinhorne, Gwinear, Hayle, Cornwall.

A. A. CLUCAS, Esq., Red Trees, Lathom, Ormskirk, Lancs.

Appointed by the National Farmers' Union of Scotland :

DAVID LOWE, Esq., C.B.E., Elvington, Gladsmuir, East Lothian.

Appointed by the Horticultural Trades' Association :

J. S. W. CRACKNELL, Esq., c/o Watkins & Simpson Ltd., 27 Drury Lane, London, W.C.2.

Appointed by the Royal Horticultural Society :

F. A. SECRETT, Esq., C.B.E., F.L.S., V.M.H., Bell Farm, Felcott Road, Walton-on-Thames, Surrey.

Appointed by the National Allotments and Gardens Society :

G. W. GILES, Esq., O.B.E., Drayton House, Gordon Street, London, W.C.1.

Appointed by the Seed Trade Association of the United Kingdom :

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The Executive Committee

(Governing Members elected at the First General Meeting 8th November, 1949)

Professor F. T. BROOKS
Professor W. BROWN
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E. H. GARDENER, Esq.
G. G. HOLE, Esq.
R. L. SCARLETT, Esq.
F. A. SECRETT, Esq.
Professor R. H. STOUGHTON
Dr. H. V. TAYLOR (*Chairman*)
Professor T. WALLACE

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Professor W. BROWN
A. A. CLUCAS, Esq.
A. L. DEAL, Esq.
E. H. GARDENER, Esq.
D. LOWE, Esq.
Professor J. W. MUNRO
F. A. SECRETT, Esq.
Professor R. H. STOUGHTON
Dr. H. V. TAYLOR
Dr. R. G. TOMKINS
Professor T. WALLACE
Professor S. J. WATSON

Co-opted Member

C. E. HUDSON, Esq., N.D.H., Ministry of Agriculture, 2 Cambridge Terrace, Regent's Park, London, N.W.1.

Buildings Sub-Committee

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G. G. HOLE, Esq.
D. LOWE, Esq.
Professor J. W. MUNRO
R. L. SCARLETT, Esq.
F. A. SECRETT, Esq. (*Chairman*)
Dr. H. V. TAYLOR
Professor T. WALLACE
Professor S. J. WATSON
Professor R. H. STOUGHTON

Farm Management Sub-Committee

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G. G. HOLE, Esq.
J. LAITY, Esq.
R. L. SCARLETT, Esq.
F. A. SECRETT, Esq. (*Chairman*)
W. F. SWIFT, Esq.

Co-opted Members

H. W. HUGHES, Esq., The Moat Farm, Abbot's Salford, Warwickshire.
E. R. HOARE, Esq., B.Sc., A.M.I.E.E., Wrest Park, Silsoe, Beds.

Watercress Advisory Sub-Committee

Professor W. BROWN — Dr. H. V. TAYLOR

Co-opted Members

Agricultural Research Council :

G. SAMUEL, Esq., M.Sc., 15 Regent Street, London, S.W.1

National Farmers' Union :

J. BIGGS, Esq., Quinar, Billington Lane, Sutton Scotney, Winchester.
Major CLIXBY-FITZWILLIAMS, Hazeldene, Healing, Nr. Grimsby, Lincs.
W. F. LYS, Esq., c/o Bedford & Jesty Ltd., Doddings, Wareham, Dors.
H. C. MILLS, Esq., Bishop's Sutton, Alresford, Hants.
T. A. ROTHERHAM, Esq., c/o A. J. Edwards Ltd., Covent Garden, London, W.C.2.
C. H. SANSOM, Esq. (*Chairman*), Croxley Hall Farm, Rickmansworth, Herts.

National Agricultural Advisory Service :

H. H. GLASSCOCK, Esq., M.Sc., Olantigh Road, Wye, Ashford, Kent.
J. O. JONES, Esq., M.Sc., Olantigh Road, Wye, Ashford, Kent.
W. E. HODSON, Esq., A.R.C.S., D.I.C., Provincial Centre, Chiltern Court, Reading, Berks.
C. H. OLDHAM, Esq., N.D.H., The George, Winchester.
F. W. SHEPHERD, Esq., N.D.H., The George, Winchester.

Organising Committee

This Committee existed only prior to the Society's incorporation (28th September, 1949)

Professor F. T. BROOKS
Professor W. BROWN
J. S. W. CRACKNELL, Esq.
Dr. C. D. DARLINGTON
E. H. GARDENER, Esq.
G. G. HOLE, Esq.
F. A. SECRETT, Esq.
Dr. H. V. TAYLOR (*Chairman*)
Professor T. WALLACE

STAFF

Director :

JAMES PHILP, B.Sc. (Glas.), Ph.D. (Lond.), F.L.S.

Plant Breeding :

D. BOYES, M.A. (Cantab.), (*Part-time*).
G. D. SULLIVAN, B.Sc. (Wales).
Assistant : J. H. MATTHEWS.

Entomology :

D. W. WRIGHT, M.A. (Cantab.).
J. A. DUNN, M.Sc. (Durham).
G. A. WHEATLEY, B.Sc. (Durham).
Assistants : H. I. SMITH, D. J. TWINN.

Physiology :

E. J. WINTER, M.C., M.Sc. (Bristol).
A. H. PARKINSON, B.Sc. (Reading), M.S. (Cornell), Ph.D. (Lond.).
Assistant : Miss G. A. PURDY.

Chemistry :

R. M. WOODMAN, M.Sc. (Leeds), Ph.D. (Cantab.), F.R.I.C., F.Inst.P.
Assistants : T. W. G. McKEAN, Miss J. LAFFLING.

Statistics :

J. A. NELDER, B.A. (Cantab.).

Watercress :

D. M. SPENCER, B.Sc. (Wales).

Administration :

Secretary : J. C. WILKINS, LL.B. (Lond.), A.C.I.S.
Accounts Clerk : J. H. L. BRIDGEWATER.
Director's Personal Secretary : Miss G. M. CRITCHLEY (resigned December, 1949).
Clerk : Miss D. PHILLIPS.

FOREWORD

I have been asked by my colleagues on the Governing Body of the National Vegetable Research Station to write a Foreword to its first Annual Report. I gladly comply, but with a request to the reader to remember that many difficulties are being encountered in the creation of a new Research Institute in present circumstances.

During the latter part of the 1939-45 war much thought was given to the needs of research in agriculture and horticulture in consequence of the necessity of increasing food production in Great Britain in future. In this connection a Survey Group, appointed by the Agricultural Research Council, the Agricultural Improvement Council of the Ministry of Agriculture and Fisheries, and the Scottish Agricultural Advisory Council, recommended that a new Vegetable Research Station should be established in view of the great national interests involved and the limited facilities available at Cambridge, where investigations had been proceeding for several years under the auspices of the Ministry and the University. H.M. Treasury agreed to this proposal, and in 1947 a Governing Body for the new N.V.R.S. was established by the Minister of Agriculture and Fisheries and the Secretary of State for Scotland, as described later in the Director's Report.

The first meeting of the Governing Body was held in October 1947, when an Organising Committee was appointed to initiate the new Station. In February 1948 the Governing Body appointed as the first Director, Dr. J. Philp, a distinguished plant-breeder who had had much experience at home and abroad. His first duty was to seek for a site for the new Station, a task which proved to be very arduous. Until the Governing Body was legally incorporated as the British Society for the Promotion of Vegetable Research in September 1949, the administrative arrangements were in the hands of the Ministry of Agriculture and Fisheries, and the Governing Body wish to record their special thanks to Mr. W. R. Black in this connection. From the date of incorporation, the staff of the Cambridge Horticultural Research Station were transferred administratively to the N.V.R.S., although continuing to work at Cambridge for the time being.

In November 1949 the Governing Body appointed an Executive Committee, which subsequently appointed various Sub-Committees. These have laboured strenuously during 1949-50, and thanks are due to the members for their constant assistance, especially Dr. H. V. Taylor, Chairman of the Executive Committee (and formerly Chairman of the Organising Committee) and Mr. F. A. Secrett, Chairman of the Buildings and Farm Management Sub-Committees.

As the Director records in his Report, the main research station is situated at Wellesbourne, Warwickshire, with a sub-station primarily for seed production at Paglesham, Essex. It is the policy of the Governing Body first to develop the station at Wellesbourne so as to provide the staff with the urgently needed laboratories, glass-houses, other buildings and the necessary services. Farming operations at Wellesbourne are being conducted with a view to enhancing the value of the land for vegetable production. Farming of the land at Paglesham is proceeding satisfactorily and a small beginning has been made with seed production there.

Unfortunately there has been great delay in providing research and other facilities at Wellesbourne, but this is in no way due to the Governing Body or the Director, who have done their utmost to hasten progress. It must be remembered that it is a particularly difficult time in which to establish a new research station especially as regards buildings and housing accommodation for the staff. It is hoped, however, that more rapid progress will be made in the future. In view of the lack of laboratories and dwelling-houses only a few additional members of staff have yet been appointed, but plans are in hand for further recruitment when the time is opportune.

The N.V.R.S. is fortunate in inheriting the valuable new strains of vegetable seeds produced by Mr. D. Boyes at the Cambridge Horticultural Research Station, including several which have not yet been placed on the market. It is also fortunate in retaining the services of Mr. D. W. Wright and his assistants, who have done notable work in the control of insect pests of carrots and peas. A comprehensive research programme dealing with all aspects of vegetable production has been drawn up for the future by the Director and his staff; this will be implemented as soon as circumstances allow, although there is no hope of carrying it out fully for some time to come. At present most of the scientific staff are being accommodated in other research institutions, for which assistance the Governing Body is most grateful.

The thanks of the Governing Body are due to the Director and his staff for their efforts in a year of the utmost difficulty. The task of the Director has been almost overwhelming. Not only has he had to prepare plans for research and the recruitment of staff but the brunt of formulating the laboratory, glasshouse, other building and service requirements has fallen chiefly on his shoulders. In addition, he has been responsible for running the farm at Wellesbourne, although he will now be relieved of this anxiety by the appointment of a Farm Manager. The Director has been most ably assisted in administrative matters by the Secretary, Mr. J. C. Wilkins.

Thanks should also be accorded to the Ministry of Agriculture and Fisheries, the Agricultural Research Council, and the local authorities of Warwickshire for their assistance. Lastly, as Chairman of the Governing Body, I should like to express my appreciation of the help given throughout the year by the representatives of the vegetable industry and by my scientific colleagues. The Governing Body has an onerous duty to perform in a difficult period, but it is fortified by the hope of building up a Research Institute which should eventually be a valuable asset to the horticultural industry and to the country at large.

Botany School,
University of Cambridge.
26th March, 1951.

F. T. BROOKS
(*Chairman of the Governing Body*).

REPORT OF THE DIRECTOR

THE CONSTITUTION OF THE NATIONAL VEGETABLE RESEARCH STATION

The National Vegetable Research Station (N.V.R.S.) at Wellesbourne, Warwickshire and its Sub-Station at Paglesham, Essex, were established under a Governing Body incorporated on 28th September, 1949, as a company limited by guarantee, not having a share capital, and having the title "The British Society for the Promotion of Vegetable Research," with its registered office at Wellesbourne.

The members of the Governing Body, twenty-three in number, include nominees of the two Agricultural Departments of Great Britain, of the Department of Scientific and Industrial Research, of various learned societies, universities and institutions concerned with horticulture, of vegetable producers (through the National Farmers' Unions of the two countries and the National Allotments and Gardens Society) and of trade interests.

The properties at Wellesbourne and Paglesham are leased to the Society by the Ministry of Agriculture and Fisheries. At the outset the Society depends for its funds on grants from this Ministry, except that if any stations are established or work is conducted in Scotland, grants will be receivable also from the Department of Agriculture for Scotland. Both Agricultural Departments will be advised by the Agricultural Research Council (A.R.C.) who will have the scientific oversight of the work and staff.

For two years prior to its incorporation, the Governing Body and its Organising Committee dealt with matters concerned with the establishment of the Society, and with the necessary preparations in advance of setting up the Research Station and the Sub-Station, including the selection of sites and appointment of some members of staff. Mr. W. R. Black of the Ministry of Agriculture and Fisheries acted as Secretary to the unincorporated Governing Body and to the Organising Committee during this period, and the members were indebted to him for his assistance in getting the Society established as a legal body.

When the Governing Body was incorporated and sites were obtained, the Executive Committee was appointed, and the following Sub-Committees were formed: Farm Management, Buildings, Staff and Research, and Watercress.

THE MAIN STATION, WELLESBOURNE

The search for a suitable site for the Research Station began in March, 1948. The task of finding a site meeting most of the requirements proved to be a long and difficult one. The Director investigated 318 properties which were offered for sale and made 71 inspections. It was not until the 29th September, 1949 that the Society obtained possession of the present site on a lease from the Ministry of Agriculture which purchased the property on the recommendation of the Organising Committee.

The site lies in Warwickshire, six miles east of Stratford-upon-Avon, five miles south of Warwick and one mile north of the village of Wellesbourne. It is almost in the centre of England, is easily reached by rail and road, and has soils and climate similar to the nearby Vale of Evesham where vegetable production is an important industry.

The property consists of 280 acres of level land. Except for thirteen acres of alluvium bordering the river Dene, all is arable land on a river-terrace of the Avon at an elevation of 150 feet. There are five soil series overlying Keuper clay, with gravel and sand deposits in some parts. The Newport series and the Wick series cover most of the property in about equal proportions. The Newport series occurs in both the stony and stoneless phases ; the surface soil is a sandy loam and drainage is free. The Wick series occurs mostly in the light phase with surface soil ranging from sandy loam to loam and with free drainage ; the surface soil of the heavy phase ranges from a sandy clay loam to clay loam with drainage slightly imperfect to imperfect. The Dunnington Heath series, which is on a block of a few acres, is a loam with drainage free to slightly imperfect. Bordering a stream is the Spetchley (formerly called Wet Worcester) series with clay loam surface soil and imperfect drainage. The parent material of all the above series is mixed drift, chiefly of red clay in the latter case. The thirteen acre meadow adjoining the river Dene is liable to flood and consists of Wyre clay developed from mixed Keuper and Lias alluvium with drainage slightly imperfect.

The mean annual rainfall is of the order of 25 inches with about two inches each month and the mean daily sunshine is about 3.7 hours. The prevailing wind is from the south-west.

It will be realised from what has been said that the property has much to commend it as a site for the Research Station, *e.g.*, geographic position, ease of access, and soil and climate near average for vegetable cultivation. Furthermore, market gardening has not been practised on it. The general opinion is that the soil has great potentialities for vegetable production which will be neither too easy nor too difficult. The acreage is big enough to allow of a farm unit as well as a research unit. The farm unit will be run with a view to increasing soil fertility and to maintaining it at the high level necessary for growing vegetables for research purposes. Essential features for field research work are met in that the land is flat and that there are different soil types without excessive soil variation. Regarding water supplies for irrigation, an assurance has been obtained that ample supplies could be procured from underground by means of a borehole and there is the River Dene on a boundary. The property is compact and most of the fields are alongside public roads.

Most of the natural requirements thus were met and in consequence the disadvantages were mainly of a type which could be overcome. There were, of course, no facilities in the form of laboratories and glasshouses for research and none of the buildings was suitable for conversion into laboratories. The property formed part of an estate where mixed farming was practised and it was operated from another farmstead on the estate. Although there were farm buildings in good repair on the property, they were designed almost entirely for livestock ; hence implement and store sheds were required. Housing for staff was inadequate ; there was no farmhouse and there were only three cottages, all in a poor state of repair—two of them not worth repairing and the third without possession until late in 1950. There was no electric power or piped water and a bridle path formed the means of access to the buildings.

Farming Operations

When the Director took charge of the farm after only a few days' notice, it was literally a bare farm without crops, stock, implements or machinery. The only remaining farm staff consisted of two men and a youth. Truly, it was a beginning from scratch.

The Farm Management Sub-Committee drew up a cropping programme based on a policy (1) to build up the fertility of the soil, (2) to clean the land, (3) to provide food for stock for the production of dung in 1950-51. The Warwick County Agricultural Executive Committee (A.E.C.) agreed to carry out all farming operations for one year in accordance with the cropping programme, on a contract basis.

The following programme was carried out :

Field No.	Acres	Crop	Approx. Yield
170	11.6	Barley	11 tons
133	6.4	Ryegrass—1st cut	Silage 30 tons
		Ryegrass—2nd cut ...	
90	36.4	Hay and bastard fallow	Hay 70 tons
147	5.6	Pasture	
	19	Mixed corn, undersown 3–4 year ley	19 tons
135	7.8	Spring oats, undersown 2 year ley	8 tons
136	10.4	Wheat, undersown 2 year ley	
100	23.3	Wheat, direct reseeded 3 year ley ...	44 tons
127	9.3	Reseeded long term ley	
128	4.5	Reseeded long term ley	(Grazed)
153 and 154 ...	6.1	Lucerne sown direct	
101	34.2	Green manured (ryegrass) and Sugar beet ...	370 tons
73 and 78 ...	29	Potatoes	
88	15.1	Potatoes	400 tons
87 and 102 ...	4	Potatoes	
	4	Carrots	56 tons
	7	Mangolds	150 tons
89	31.1	Green manured (tares followed by rye)	
70 and 75 ...	13.3	Pasture	(Grazed)

It may be pointed out that 261 acres of the total of 280 came under the plough during the year. In addition, almost a mile of boundary fencing was erected, fences were repaired and new gates were erected ; hedges were laid and trimmed, others were removed and over-mature hedgerow trees were felled ; a gravel pit of five acres was filled in and brought into cultivation ; farm buildings were repaired ; 80 cattle belonging to the County A.E.C. were wintered in the yards, 15 cattle were summer-grazed on the river meadow ; and 50 tons of straw were made into compost.

Owing to the inadequate and uncertain supply of labour in particular, and to the lack of equipment on the spot, it will be appreciated that farming operations during the year were carried out under great difficulties.

In preparation for taking over farming operations independently of the County A.E.C. on 1st October, 1950, implements and machinery were purchased during the

summer. Attempts were also made to recruit farm staff but through being unable to offer housing, little success was achieved. In July, the Ministry approved the appointment of a farm manager. The post was then advertised and selected candidates were interviewed in September. The post was offered to and accepted by Mr. T. J. Norwood who, owing to other commitments, could not take up his new duties until the end of March, 1951. In view of this it was arranged for a farm foreman to be appointed without delay.

THE SUB-STATION, PAGLESHAM

On the 29th September, 1949, the Ministry also leased to the Society 150 acres of land at Paglesham in Essex for a Sub-Station to be used primarily for the multiplication of stocks of seed of vegetables bred at the main station or elsewhere.

Paglesham is about nine miles north of Southend. The land is flat and the soil is a fertile loam. The rainfall is low with an average of about 20 inches per year. Essex is the main vegetable seed producing area in England owing to its suitable climate and soil conditions. The advantage of having a sub-station in this area for the early stages of seed multiplication is obvious but, in addition, it is intended that problems peculiar to this work will be investigated and that vegetable growing under these relatively dry conditions will be studied.

The property includes farm buildings, a farmhouse (East Hall) and two cottages. It forms part of a large estate owned by the Ministry and farmed in 1949-50 by the Agricultural Land Commission. The Farm Management Sub-Committee designed a cropping programme with the object of building up soil fertility to the degree necessary for the production of vegetable seed and of ensuring that the land was thoroughly clean. It was also arranged that some vegetable seed production work should be started on a small scale. In order to facilitate the execution of this programme, the property was re-let for one year to the Agricultural Land Commission who carried out the cropping programme, the work on the areas under green manuring, fallow and vegetable seed production being done on a repayment basis.

The following cropping programme was carried out :

Field No.	Acres	Crop
60 and 105 ...	19.5	Green manured (tares followed by rye)
106	6.8	Potatoes
48	12.2	Oats
	27.2	Barley
	8.2	Fallow
109	5.2	Wheat
132	9.9	Potatoes
54 and 112 ...	11.4	Pasture
128	2.2	Orchard
126	38	Peas
	7	Plant breeding and seed production material : Brussels sprouts, Onions, Peas

DEVELOPMENT

Wellesbourne

Much effort and time were spent in planning the future development of the Research Station but the amount of development in the form of new buildings which was achieved during the year was disappointingly meagre ; in fact, it amounted to two huts. A second-hand wooden hut was erected in January 1950, with the modest dimensions of 12ft. by 15ft. to provide office accommodation for the Director, Secretary and a shorthand-typist. For various reasons the erection of an asbestos 'Handcraft' hut containing four offices was delayed until September. Before this time, pressure on space in the wooden hut had become acute with the arrival of one of the research workers and an accounts clerk, making a total of five persons. Four moved into the 'Handcraft' hut before it was completed, prefering the absence of doors and the noise of workmen to the congestion of the wooden hut. Paraffin oil was the source of artificial light and heat, water was carried from a well and rubber boots were essential in wet weather.

Meetings of the Executive Committee and of the Buildings, Farm Management, and Staff and Research Sub-Committees were held separately and jointly to formulate development plans for the Station. A scheme was completed by April when an architect was appointed to produce plans, specifications and estimates in accordance with a prepared schedule of building requirements. This schedule was drawn up on the basis of the envisaged future programme of research involving seven departments ; Plant Breeding, Pathology, Entomology, Physiology, Irrigation, Chemistry and Statistics, and paying regard to the needs of the staff required for these departments and for administration. It also allowed for the anticipated extension of farming activities to vegetable cultivation with the necessary increase in the staff of field workers.

It was agreed that the building development should take place in three phases. First, water and electric power were to be provided ; an entrance road and a key road through the middle of the farm were to be made ; farm buildings were to be erected (using the Ministry of Agriculture's standard building components) adjacent to the existing farm buildings, comprising implement and machinery sheds, workshops, store sheds—one to be fitted and used temporarily as laboratories until the main block of laboratories was built, a grading, washing and packing shed and a canteen ; three pairs of cottages were to be built near the farm entrance for workers whose duties required them to live on the property, also a farm manager's house near the farm buildings and a director's house elsewhere on the property ; the Stratford-on-Avon Rural District Council were to be asked to erect thirty-eight cottages in addition to their housing programme in Wellesbourne, to accommodate farm workers and some research workers.

The second phase was to follow with the erection of about half of the main block of laboratories and offices together with glasshouses, frames and the necessary adjuncts for research purposes. This two-storey block was to be sited on the south side of the entrance to the farm, the glasshouses being adjacent to it and on the west side. The main block was to be designed as a whole and in such a way that half of it could be built as a unit providing the necessary accommodation and facilities for the research and administrative staff in the earlier stages of development, the remainder to be added at a later date. It was thought that this second phase might be completed during 1952.

The third phase was to be the completion of the block of laboratories and offices, probably in two sections during the succeeding two years.

The East Midlands Electricity Board was approached, also the British Electricity Authority, and an assurance was obtained that the necessary lines and electrical power would be provided by April, 1951. The delay arose because power would require to be supplied from a new line which was about to be brought to the district ; existing lines across the property apparently were incapable of carrying the extra load required.

Shortly before the Society obtained possession of the farm, the Stratford-on-Avon Rural District Council began to sink a borehole to the north of the property for water supplies. Further assurances were obtained, on good authority, that underground water supplies in this area would be ample for the needs of both the Rural District Council and the Research Station. As a result of enquiries, however, it appeared that the Rural District Council water scheme would not be functioning for some years and that it was unlikely that enough water could be spared to meet the needs of the Research Station. Further advice was obtained and it was decided that steps be taken to sink a bore-hole on the property. Being a controlled area where normally a licence to sink a borehole for abstraction of water must be procured from the Ministry of Health, the matter was placed in the hands of the Ministry of Agriculture in May, 1950.

In March, 1950, the Stratford-on-Avon Rural District Council, with the approval of the Ministry of Health, agreed to increase their housing programme in Wellesbourne and make houses available for letting to employees of the Research Station. It was understood also that, apart from unforeseen difficulties, the first batch of sixteen houses would be ready for occupation by March, 1951, and that half of the number could be rented by Station employees. Difficulties arose and building had not started by the end of September.

The architect provided a block plan of the whole development scheme for the Station, together with sketch plans, outline specifications, and estimates of costs for the first phase as described above. After receiving the approval of the committees concerned, the plans were submitted in July to the Ministry of Agriculture and the Agricultural Research Council for their approval prior to approaching the Treasury for sanction to execute the scheme. The Ministry and the A.R.C. had previously recognised the urgency of this phase of the development programme and had approved it in principle. A quantity surveyor was appointed in readiness to begin his duties immediately the scheme received final sanction.

In the meantime, slow progress was made in connection with the water supply, and it is only recently that permission for the Station to sink its own borehole has been agreed upon in principle. The delay about the water supply resulted in postponement of the plans for development being submitted to the Treasury by the Ministry. Consequently there is bound to be an adverse effect on the functioning of the Station as originally hoped for in 1950-51.

Paglesham

An arrangement was arrived at with the Ministry of Agriculture whereby certain of the farm buildings were to be repaired, others in a dilapidated state were to be demolished and replaced by the following new buildings suited for the work of this Sub-Station ; a general seed drying shed with field laboratory, a special onion drying shed and an implement shed. It was also proposed that six cottages for farm workers should be built. Apart from the repair work, this development programme was regarded as being less urgent than that of the main station at Wellesbourne.

STAFF

Five members of staff were appointed in advance of the incorporation of the Society on the 28th September, 1949, and consequently were engaged as temporary officers of the Ministry of Agriculture which met all the expenditure incurred.

The Director was appointed as from the 1st March, 1948. Between then and September, 1949, he was concerned with the search for a site for the Research Station and with the establishment of the Society as a corporate body. He also made a study and tour of inspection of the vegetable industry, visited Research Stations and Universities, attended the 8th International Genetics Congress in Sweden in 1948, and gave lectures on vegetable research at various places.

Miss G. M. Critchley was appointed as Personal Assistant to the Director on 27th September, 1948, and resigned on 21st December, 1949, as she did not wish to transfer to Wellesbourne from London.

Mr. G. D. Sullivan was appointed on 1st September, 1948, and was seconded to the Cambridge Horticultural Research Station as assistant plant breeder to Mr. D. Boyes.

Mr. E. J. Winter was appointed on 9th March, 1949. He was kindly provided with facilities for carrying out physiological studies by the Long Ashton Research Station, Bristol University, until 14th August, 1950, when he transferred to Wellesbourne.

Mr. D. M. Spencer was appointed on 12th September, 1949, and through the generosity of the N.A.A.S., he was given accommodation and equipment for carrying out research on watercress diseases at the N.A.A.S. Sub-centre at Wye, Kent, under the guidance of Mr. H. H. Glasscock, the Advisory Plant Pathologist.

On 1st October, 1949, the above staff became employees of the Society and hence members of the staff of the N.V.R.S. On the same date, the research staff of the Cambridge Horticultural Research Station (H.R.S.) was taken over by the N.V.R.S. as employees of the Society ; Mr. D. Boyes, plant breeder (part-time) ; Dr. R. M. Woodman, chemist ; Messrs. D. W. Wright, J. A. Dunn and G. A. Wheatley, entomologists. Mr. Boyes was also engaged part-time on strawberry breeding together with an assistant Mr. H. Williams, and the grant for this work, provided by the Agricultural Research Council, was administered by the N.V.R.S. This arrangement was to continue until September, 1951, when the work on strawberries would be done elsewhere. Provision was made for these men and Mr. G. D. Sullivan to continue their work at the Cambridge School of Agriculture and it was arranged that the entomologists and Mr. Sullivan would be transferred to Wellesbourne as soon as possible and by 30th September, 1951, at the latest. The accommodation in the School of Agriculture and the land hitherto occupied are required for other purposes by Cambridge University from 1st October, 1951. Mr. Boyes, who officially retired in September, 1948, has since been employed on a temporary basis, but his services will cease in September, 1951. It is yet uncertain whether Dr. Woodman will transfer to Wellesbourne. It was anticipated that part of the transfer could be accomplished in March, 1951, but, owing to the delays in the building development programme, it became obvious that this could not be done.

Mr. J. A. Nelder was appointed on 10th October, 1949, as statistician and he was kindly given facilities at the Rothamsted Experimental Station, Harpenden for carrying out his work under the guidance of Dr. F. Yates, head of the Statistical Department. In June, 1950, he went to work at research stations in France for a period of five months under a scheme arranged by the A.R.C. for the exchange of scientists.

Dr. A. H. Parkinson was appointed on 22nd August, 1950, and was generously provided with facilities at the Imperial College of Science, London, for carrying out physiological research under the guidance of Professor F. G. Gregory.

Mr. J. C. Wilkins was appointed Secretary to the Society and to the N.V.R.S. on 14th November, 1949. He occupied the Ministry office in London, which the Director vacated on 1st October, until 28th December, when he joined the Director at Wellesbourne.

Miss D. Phillips was appointed as shorthand-typist at Wellesbourne on 24th January, 1950, and resigned on 30th September.

Mr. J. H. L. Bridgewater was appointed as accounts clerk at Wellesbourne on 4th September, 1950.

During the year, certain Conferences were attended by members of the staff. The Director, Mr. G. D. Sullivan and Mr. D. M. Spencer attended the Plant Breeders' Conference, which was organised by the A.R.C. and held in Edinburgh in August, 1950. Messrs. D. W. Wright, J. A. Dunn and G. A. Wheatley attended the A.R.C. Conference on the Control of Pea Moth and other Pea pests, held in February, 1950, and submitted reports. Other Conferences attended by Mr. D. W. Wright included the N.A.A.S. Plant Protection Conference held in Cambridge in January, 1950, at which he read a paper, the A.R.C. Conference on Aphid Research in March, 1950, to which he submitted a report, and the meeting of the Association of Applied Biologists held in Edinburgh in July, 1950.

RESEARCH

In the reports and reviews given later by those members of the staff who were previously with the Cambridge H.R.S., brief accounts of their earlier work are included in order to provide a better appreciation of the work done during 1949-50. Acknowledgment is made, therefore, that the work done at Cambridge prior to 1st October, 1949, and reported upon here, was carried out by the staff of the Cambridge H.R.S.

An interesting development of the plant breeding work is the possibility of improved crops of Brussels sprouts being grown from hybrid seed, *i.e.*, the commercial seed will be produced directly from natural crosses between chosen unrelated parents as opposed to the normal practice where commercial seed of a variety is produced from natural crosses between related parents. Work was continued with mutant seed characters in winter cauliflower and onions with a view to introducing them into varieties so that admixture or outcrossing might be recognised readily. Further work was done with some promising new varieties of brassicas and onions, and nucleus stock seed supplies of varieties already distributed were maintained.

On the entomological side, previous studies under laboratory conditions had shown that pea moths began to emerge from the soil when it had absorbed a given amount of heat. Under uniform temperature conditions, a constant total of "day degrees" was necessary to transform the overwintering larva in the soil through the pupal to the adult stage, "day degrees" being the number of degrees by which each day's soil temperature exceeded a given minimum. In 1950, the method was tested in the field using different soil types. The results showed that there was a close correlation between the time of emergence and the accumulation of a given number of day degrees, and that for each soil type, the time of emergence bore a direct relation to the capacity of the soil to absorb and conduct heat. It was also found that the deeper the larvae were in the soil, the later did emergence begin. Effective control of the pea moth with insecticides is dependent on precise knowledge of the time of emergence in the field and it would appear that the above method may provide a basis for obtaining this knowledge. Plot experiments showed that a systemic insecticide (*Pestox III*) was ineffective against this pest. Laboratory tests revealed that the mature larva was very resistant to DDT dusts and residues, while the young larva was very susceptible. Further data were collected on the parasites of this insect.

Population studies on pea aphid in 1950 showed that in spite of small overwinter egg numbers, damaging infestations could occur on early peas if natural environmental factors were favourable at the time of migration and at the building up stage which succeeded it. These studies emphasised the extreme vulnerability of aphid populations to natural controlling agencies which govern the ability of the aphid to produce high populations and to cause damage of economic importance.

Experiments have shown that the carrot fly may be controlled either by using benzene hexachloride on the seed bed before sowing, or by applying it to the carrot seedlings along the rows. In the latter case it may be applied in certain oils and there appears to be a high probability that the light mineral oil sprays now being used for the control of weeds in the carrot crop may, at the same time, be a suitable medium for application of the BHC for the control of the carrot fly. By using BHC of high gamma content a control of the pest may be gained, probably with little risk of tainting the crop.

Studies on the preparation and effect of DDT dust insecticides have shown that the toxicity of a dust prepared by impregnating the filler with DDT dissolved in a volatile solvent was considerably greater than that of an orthodox dry-ground, ball-milled mixture. It would appear probable, therefore, that dusts prepared by the former method would require less DDT to effect the control of a given pest and would thereby reduce the quantity of noxious residues remaining on the crop.

Physiological experiments were carried out on lettuce and garden beet.

Breeding and seed production work with summer lettuce in this country is hindered by the fact that it usually flowers too late to give a reasonable crop of seed. Investigations were made, therefore, on some factors which might induce early flowering. It was felt that this work might also provide some information on the problem of bolting in commercial crops. It was found that the date of bolting could be hastened by suitable vernalisation, day-length, temperature, and nitrogen/potassium status of the growing medium. None of these factors by itself hastened bolting sufficiently to remove the above-mentioned difficulty but the evidence suggested that combination of some or all of these factors at suitable levels might prove satisfactory. Modification of the vernalisation treatment, in that the temperature was below 0° C., kept summer lettuce in the hearted stage for a longer period than untreated lettuce, an effect which might be of practical value.

Cheltenham Greenleaved Beet is a popular variety but has the reputation of being unreliable in germination. Experiments showed that the environmental conditions under which commercial seed was produced had an effect on germination. It is anticipated that the problem is both genetical and environmental in nature ; further study may determine which has the greater effect and which aspect of the problem may be remedied more readily.

Advantage was taken of an opportunity, kindly provided by Long Ashton Research Station, of obtaining a thorough experience of sand culture technique.

The long term manurial experiments with a rotation of vegetables were continued and gave results which will add to knowledge of the cumulative effects of the different treatments. Sand culture experiments on the nutrition of vegetables were extended to cauliflower where the treatments consisted of varying amounts of potassium in nutrient solutions.

The steady depression in yield of watercress beds during the past ten years or so has become serious, reaching as much as 30 per cent. in Hampshire. Apart from the research at the Cambridge School of Agriculture, other investigations on this crop had been made from time to time. The Cambridge work was about to come to an end, and, on the instigation of the Agricultural Improvement Council, the A.R.C., and the N.A.A.S., it was agreed, therefore, that the Station should take up research on this crop.

A survey of commercial watercress beds in 1949-50 showed that the depression in yield was mainly brought about by an unhealthy condition of the plants which was associated with root distortion (crook root). It was found that two fungal bodies

were associated with the distortion of the roots but it has not yet been possible to determine whether these bodies are members of the same or of different species of the order *Plasmodiophorales*. Attempts to infect healthy roots under controlled conditions have failed so far, but see footnote on page 56.

On the statistical side, exploratory work was done and experience gained on experimental design and sampling techniques to be used in the various lines of research at the Station. Assistance was also given to research stations on statistical problems concerned with horticulture and agriculture.

Acknowledgments

The Director wishes to express his appreciation of the generous assistance given by other research centres to the Station during its early stages of development. Special mention in this respect must be made of the Imperial College of Science, London ; the Long Ashton Research Station, Bristol ; the N.A.A.S., Wye ; the Rothamsted Experimental Station, Harpenden ; and the School of Agriculture, Cambridge.

He also wishes to thank the N.A.A.S. for help given in the search for a site for the Station; the Warwick County A.E.C. and the Agricultural Land Commission for assistance in carrying out the farming operations at Wellesbourne and Paglesham respectively ; and other Bodies for their co-operation.

Grateful acknowledgment is also made to Mr. J. A. Nelder for help in the editing of this annual report and to all the staff and employees for what has been accomplished in the first year of the Station's existence.

Finally, the Director wishes to thank the Executive Committee and the various Sub-Committees for their unfailing assistance in a difficult year.

National Vegetable Research Station,
Wellesbourne,
Warwick.
1st March, 1951.

J. PHILP,
Director.

PLANT BREEDING REPORT

By D. BOYES

Notes on varieties which have been distributed

Brussels sprouts : Cambridge Nos. 1, 3 and 5

Work with these varieties was begun in 1925 and 1926. All three were first distributed through the Norfolk Seeds Association, No. 1 in 1936, Nos. 3 and 5 in 1938. For reasons which will be clear to plant breeders and to growers these varieties have been allowed to retain a certain amount of variability.

No. 1, when properly grown on a suitable soil, is an early sprout of medium height.
No. 3 is taller, later, and more vigorous than No. 1 and could be called a "general purpose" variety.
No. 5 is tall and late.

Cauliflower : Cambridge Earliest (No. 5), Cambridge No. 6, and Cambridge Early (No. 7).

Work began on No. 5 in 1933 and seed was first distributed in 1943. Nos. 6 and 7 date back to 1929. No. 6 was distributed in 1944 and No. 7 in 1937. Distribution of the three varieties was first carried out by Messrs. Cooper, Taber Ltd.

No. 5 comes in a fortnight before No. 7. It has a distinctive yellowish seed and the curds do not turn pink with age.
No. 6 is intermediate.
No. 7 comes in a fortnight before "All the Year Round."

Onions : Cambridge No. 2 and No. 10.

These varieties date back respectively to 1932 and 1923. The first distribution of seed took place in 1949 through the National Institute of Agricultural Botany (N.I.A.B.).

No. 2 is a pale brown thick flat onion, varying little in colour, shape and size when properly grown.
No. 10 is also pale brown in colour, but globular in shape. As the globular shape represents a heterozygous condition in this variety, great care is needed in selecting the material for stock seed production.

Notes on varieties not yet distributed

These vegetables can be classed as follows :

(1) varieties which have been tested by the N.I.A.B. and await distribution ;
(2) varieties of which the N.I.A.B. trials are not yet completed ;
(3) varieties not yet tested by the N.I.A.B.

(1) Winter Cauliflower*

MX or Cambridge Hardy Late, is based on material which was obtained from Derbyshire in 1932. A number of lines have been developed ; Cambridge Hardy Late happens to be one which withstood the severe winters of 1939-40 and 1946-47. The time of maturity varies according to the season and is usually at the end of April or early in May.

X10 and X13 also date back to 1932. They are dwarf winter cauliflower of a distinct type needing market garden conditions. Time of maturity : end of March or early April.

* The term "Winter Cauliflower" is used in place of the word "Broccoli".

Brussels sprouts

Cambridge Special was developed in response to a request for a sprout suitable for canning and for the restaurant trade which would withstand, without "blowing," moist (but not waterlogged) conditions such as are found in certain parts of the East Anglian Fens where sprout growing is possible.

Breeding material has been grown for many years, sometimes on a very large scale, on Messrs. Chivers' Burnt Fen Estate. Tests in the south-west (*e.g.*, at Cannington) have so far been satisfactory.

Cabbage

Cambridge Drumhead was produced in response to many complaints from salesmen that the "Christmas Drumhead" cabbages sent to them were too large for the retail trade. This variety is, in effect, a smaller and neater version of the type.

(2) Cabbage

Cambridge February is a hardy, late variety, smaller and later than "January King" and without the red coloration of that variety. It has been thoroughly tested under commercial conditions.

Cambridge Red resulted from work begun in 1933 at the request of the Ministry of Agriculture and Fisheries. It appeared that, on account of the unsuitability of English red cabbages for the pickling trade, material had to be imported from Holland. A parcel of cabbage heads was, therefore, obtained from a firm of picklers. These heads had been imported from Holland and were of the type required. They were rooted in a nutrient solution, potted, grown on, and used for breeding. Cambridge Red represented the only stock, out of a large number, for which room could be found at the Station. It is extraordinarily solid and, even in the semi-arid conditions of the Cambridge Station, attains a weight of twelve pounds from a spring sowing. It is unsuitable for autumn sowing.

(3) Winter Cauliflower

Roscoff. The material used in this work, begun in 1930, was obtained from a stock imported from France by the Ministry of Agriculture. The surviving material contains valuable types which were present in imported stocks in the early nineteen-thirties but which now seem to be missing from commercial stocks. There was formerly (in 1938) a series of varieties in possession of the Station, at least three of which, including X9, were ready for distribution and of which more than ample supplies of seed were available. Attempts were made during the war to keep all this material in being. Some stock seed was actually produced, but it became more and more difficult to find growers able and willing to deal with this crop and especially with seed production. In order to avoid total loss, small mass selections were made at the Cambridge Station. Although Roscoff rarely survives a Cambridge winter, it is possible to select plants of the required types in the autumn, grow them under glass, and obtain seed the following year. This procedure was adopted. One of the varieties obtained in this way (RL) has given good results in the south-west.

Cabbage

Cambridge Late Drumhead. This variety is based on material, probably of French origin, selected in 1932. It is larger than Cambridge Drumhead, hardier, and has a somewhat different type of foliage.

January King Selection. This selection has been made with the object of producing a greater degree of uniformity in size, time of maturity, and type of plant; also neater and smaller heads, more suitable for the retail trade.

Onions

Nos. 1, 28 and 33 are pale or medium brown in colour. Work with Nos. 28 and 33 began in 1923 and both varieties are derived from single plants selfed in that year. No. 1 has a strong foliage and does well in a dry season. No. 28 is ready about the same time as No. 10 and succeeds in ordinary market garden conditions. No. 33 is later and paler in colour and, in order to be seen at its best, needs moisture and good treatment. Nos. 28 and 33 are heavy-weights reaching a maximum weight of 16 oz. at the Cambridge Station, except in a drought season.

Work done during 1949-50

Nucleus stock seed was produced of the varieties listed below :—

Varieties which have been distributed

Brussels sprouts :	Cambridge Nos. 1 and 3
Cauliflower :	Cambridge Earliest No. 5
Onions :	Cambridge Nos. 2 and 10

Varieties about to be distributed

Winter Cauliflower :	Cambridge X13
Cabbage :	Cambridge Drumhead

A variety, trials of which are not yet completed

Cabbage :	Cambridge February

Promising varieties not yet tested in trials

Winter Cauliflower (Roscoff) :	Cambridge X9 (provisional name)
Cabbage :	Cambridge Late Drumhead
	January King Selection
Onions :	Cambridge Nos. 1, 28 and 33

Plants of the varieties listed below were grown and selected for the production of nucleus stock seed in 1951 :—

Brussels sprouts :	Cambridge No. 3
Winter Cauliflower :	Cambridge X10
Onions :	Nos. 2 and 10 ;
	Nos. 1, 28 and 33

Seed was produced from breeding material of winter cauliflower, peas and onions.

Material grown and selected for further breeding work included early cauliflower of Erfurt type, a range of selections from the winter cauliflower Cambridge MX Hardy Late, and various Brussels sprouts and onions.

Where N.V.R.S. seed was supplied to the N.I.A.B. for multiplication, assistance was given in the inspection and rogueing of the plants in the seed crops.

Experiments were carried out with the object of producing winter cauliflower and onion varieties with seed of a distinctive character so that adulteration or out-crossing can be detected.

It has been found that crosses between individuals drawn from different Cambridge varieties of Brussels sprouts give progeny superior in some respects to either parent. Small scale outdoor interplantings of certain of these varieties, with natural intercrossing, have given good results. It remains to try out this procedure on a field scale.

THE CONTROL OF THE CARROT FLY
(*Psila rosae* Fab.)
WITH BENZENE HEXACHLORIDE

By D. W. WRIGHT

INTRODUCTION

During the period 1940-44 an intensive study of the biology and ecology of the carrot fly (*Psila rosae* Fab.) was made by workers at Cambridge (Wright *et al.*) (3), (5). Arising from this, a method of control was developed which depended largely on finding that the flies passed most of their time in shelter around the crop, making excursions to it at infrequent intervals for the purpose of egg laying. By applying insecticides to these shelter sites—hedges, dykesides, etc., very high mortalities of flies could be obtained and the carrot crop thereby largely protected. Sprays containing a poison bait were first used but these were later superseded by DDT. These treatments have been extensively used in East Anglia and in most cases have given very satisfactory commercial control of this pest. However, cases have occurred from time to time where the control given has been very imperfect. On investigation these have been found to be associated with conditions of heavy shelter around the crop, such as woodlands, trees or high weed-covered banks. These conditions give considerable shelter to much of the carrot field, and high populations of the flies may then become resident in the carrot crop for long periods. To combat this, treatment of the whole crop with a suitable insecticide would appear necessary.

On a plot or garden basis, treatment of the surrounding shelter and the carrot foliage with a poison bait or with DDT has been shown by experiment to be largely ineffective. Migrant flies may pass through such a treated barrier and oviposit before being affected by insecticidal residues. To be effective under these conditions there is required either a very effective and persistent insect repellant, or an insecticide showing long residual action coupled with a rapid knockdown effect. Such materials are so far not available commercially.

Certain of the chlorinated hydrocarbons, however, have been shown to be very persistent soil insecticides, and the gamma isomer of benzene hexachloride (BHC) has been found to be particularly effective in preventing carrot fly attack. Glendenning and Fulton (1) have shown that a dust containing five per cent. BHC (crude isomeric mixture) applied to the open drill before sowing or to the seedlings in May, would give a good control of the first and second generations of this insect. The lowest rate of application which gave this result was 10 lb. crude BHC per acre containing an equivalent of about 1 lb. of the gamma isomer. Newton *et al.* (2) also reported satisfactory results with a dust containing crude BHC applied to the seedling carrots.

In experiments carried out by the writer in 1945 and 1946, it was found that high dosages of dusts containing crude BHC gave almost perfect control of heavy carrot fly infestations. However, when the carrots thus treated were cooked, and in some cases when eaten raw, they showed either a marked lack of carrot flavour or possessed a very unpleasant taste which could be variably described as earthy, musty, strong, metallic, etc. Moreover, potatoes and certain other root crops were also tainted when grown on land treated in the previous year with BHC at the higher rates of application. The problem therefore resolved itself into finding a rate and method of application of the BHC which would give a satisfactory control of the carrot fly but would not, at the same time, affect the flavour of the carrot or subsequent crops.

From 1945 to 1949 inclusive, the materials used contained crude BHC of which 12.5 per cent, was gamma isomer. In 1950, a BHC containing 90 per cent. gamma isomer became available and was used throughout. As this is the most active in-

secticidal isomer of BHC, the high gamma materials may be used at much lower rates than those of the parent mixture without loss of insecticidal efficiency. Furthermore, although all isomers cause tainting, the gamma is among the least troublesome in this respect (4). Therefore, with the advent of high gamma BHC materials, the problem of achieving a control of the carrot fly without affecting the flavour of the crop would appear to have been materially eased.

Throughout these experiments, samples of the carrot or other crops from the various experimental plots were cooked and tasted. A uniform cooking method was used and the samples, under code, were arranged in a random order for a panel of from seven to twelve tasters. The tasters rated the samples according to the presence or absence of the normal flavour associated with the crop and noted also the presence of foreign flavours. By awarding a system of points relating to the intensity of the flavour detected, it was possible to deduce which samples had been materially affected by the treatment.

1946 Experiments

In 1946, a three per cent. BHC dust was applied three times at fortnightly intervals in May and June to early sown carrots. This treatment was repeated in August and September for the second generation. Two series of plots were treated in this way, the total crude BHC applied in one case being 60 lb. and in the second 70 lb. per acre. The dusts were put on with a piston-type hand machine, and were directed into the carrot row where some adhered to the foliage but most fell on to the crowns of the carrots or on the soil nearby. With both rates of application an almost perfect control resulted, the untreated plots being severely attacked. The final yield from the treated plots was more than four times that from the untreated whilst there were marked differences in quality. Tasting tests, however, showed that the treated carrots were very severely tainted and they were judged as being inedible.

To test for the persistence of the BHC in the soil, a range of root crops was grown in 1947 on the land which had been treated in the previous year. These were harvested and samples taken for flavour tests in September. Potatoes were very heavily tainted whilst carrots, turnips and swedes had either lost their characteristic flavours or had an earthy taste. Potatoes, carrots and turnips were again grown on the same land in 1948, without further applications of BHC. No evidence of tainting was then obtained with any of the crops.

The incidence of carrot fly attack on these plots and on adjoining land in 1947 and 1948 was very low and it was not possible to determine any effect of BHC residues on carrot fly attack.

1947 Experiments

In 1947, a 2.5 per cent. BHC dust was applied along the rows during May and June as in 1946. The various treatments resulted in the application of BHC at the rates of 10.5 lb., 9.5 lb., 7.4 lb. and 4.5 lb. per acre. Replicated plots of each treatment were used but no appreciable carrot fly attack developed. Palatability tests done in November showed that the 10.5 lb. and 9.5 lb. rates of application had produced definite tainting whilst the two lower rates had caused a loss of carrot flavour. Tests at the same time on parsnips which had been treated with BHC dust in the same way as the carrots but at the rate of 6.2 lb. BHC per acre, showed marked tainting. In 1948, carrots and potatoes were grown on the same land which in 1947 had received BHC at the rates of 9.5 lb., 7.4 lb., and 4.5 lb. per acre. The residues from the 9.5 lb. rate caused tainting of the potatoes and poor flavour in the carrots ; at the two lower rates, however, no effect on either crop could be detected.

1948 Experiments

In 1948 a replicated plot trial was carried out with early sown carrots using a 2.5 per cent. BHC dust. This was applied to the rows as before, and single and double

dustings were carried out. Examination of the plots in July showed that little first generation attack had occurred and no further insecticidal applications were made. The crop was clamped in November ; in March 1949 it was examined for carrot fly attack and samples were cooked and tasted for flavour. Details of the treatments carried out and the results obtained are shown in Table I.

TABLE I

Control of Carrot Fly with BHC, Cambridge, 1948

Treatment	Rate of BHC dust per application	Rate of BHC (crude) per acre for all applications	Roots unattacked %	Roots attacked and unsaleable %
1. 1 application 13th May	1 lb. per 100 row yds.	3.7	80	2
2. 1 application 13th May	1 lb. per 80 row yds.	4.5	81	0
3. 2 applications 13th May and 3rd June	1 lb. per 100 row yds.	7.4	83	1
4. 2 applications 13th May and 3rd June	1 lb. per 80 row yds.	9.0	92	0
5. Untreated	nil	nil	30	31

2.5% BHC dust used throughout.

All four BHC treatments gave a substantial degree of carrot fly control but in both cases where double dustings were carried out (treatments 3 and 4), the roots were of a very poor flavour. Where only single dustings (treatments 1 and 2) were given, however, the flavour was normal as with the untreated crop.

1949 Experiments

A similar replicated plot experiment using 2.5 per cent. BHC dust was carried out in 1949. Treatments were applied as for the control of the first generation but by July, as in 1948, only a very slight attack had developed and no further insecticidal treatments were applied. The carrots were clamped and later examined and tasted. This showed that 2.5 per cent. BHC dust applied to the rows at rates of 3.7 lb. and 4.5 lb. crude chemical per acre had greatly reduced the second generation attack, thus confirming the results obtained in the previous year. In addition, no tainting or lack of flavour could be detected in the samples tasted. The 2.5 per cent. BHC dust was also applied directly to the soil in this experiment being broadcast and lightly raked into the seed bed before sowing. It was used at two rates 2.8 lb. and 4.2 lb. BHC (crude) per acre and, with both, a very imperfect control of the second generation of carrot fly was obtained. The higher dosage used compares in rate per acre with that which proved successful when limited to the carrot rows. In the latter case, however, the concentration of BHC in the soil in the immediate vicinity of the roots must have been at least five times greater than for the broadcast method.

1950 Experiments

In 1950, replicated plot experiments were carried out at Cambridge and on fen soil at Mepal, Isle of Ely. The BHC used in these experiments contained 90 per cent. of the gamma isomer and thus for equal BHC contents, the 1950 materials contained some 7.5 times as much gamma isomer as those used in previous years. Since it appeared probable that the insecticidal efficiency of the two types of BHC would be similarly related, much lower rates of the high gamma BHC were used.

A dust of low BHC content was used, as in previous years, both as a pre-sowing seed-bed treatment and along the rows to the carrots. A dust containing 40 per cent. BHC was used as a seed dressing to test the value of this method of application for carrot fly control. It was applied to the seed at the rate of 2.5 parts per 100 parts of seed (w/w). BHC was also dissolved in tractor vapourising oil (T.V.O.) and used at low concentration, the mixture being put on to the seedling carrots with a hand atomiser. Sufficient was applied to cause almost complete wetting of the foliage and some was deposited on the soil near the crown of the carrots. The carrots were not sprayed until they carried at least two rough leaves and, apart from a slight and temporary yellowing of the foliage, no lasting phytocidal effects resulted. For direct comparison with this, T.V.O. was used alone, applied in the same manner to the crop and at the same gallonage per acre. The increasing practice of using a light mineral oil for the control of annual weeds in carrots, presents an opportunity for the development of a dual purpose spray, controlling both weeds and carrot fly.

Table II shows details of the various treatments carried out and the results obtained in a replicated plot experiment at Mepal on early sown (March) carrots. The treatments were primarily directed at the control of the first generation of the carrot fly ; only in treatments 8 and 9 were additional materials applied against the second generation.

TABLE II

Control of the First Generation of Carrot Fly, Mepal, 1950

Treatment	Total weight of BHC (90% gamma isomer) applied per acre oz.	Carrots unattacked 20th July %
1. Seed treated with 40% BHC at rate of 2.5 parts per 100 parts seed	0.9	96.5
2. T.V.O. only 1 application 25th May, 18 gals. per acre	nil	81.5
3. T.V.O.+BHC, 1 application, 25th May, 12 oz. BHC/acre, 18 gals. T.V.O./acre ...	12.0	94.5
4. T.V.O.+BHC, 2 applications 30th May and 13th June. Each application 18 gals. T.V.O. per acre, 9.1 oz. BHC/acre... ...	18.2	100
5. BHC dust to seed-bed. 12.3 oz. BHC/acre	12.3	93.5
6. BHC dust to seed-bed. 16.4 oz. BHC/acre	16.4	92.5
7. BHC dust to carrot rows, 1 application 25th May, 4.8 oz. BHC/acre	4.8	85.0
8. BHC dust to the rows. 2 applications 25th May and 4th August. Each application 4.8 oz. BHC/acre	9.6	94.0
9. BHC dust to the rows. 3 applications 25th May, 4th August, 19th August. Each application 4.8 oz. BHC/acre	14.4	94.5
10. Untreated	nil	76.0

Significant Differences

Treatment 4 significantly different from all other treatments.

Treatments 1, 3, 5, 6, 8 and 9 significantly different from treatment 10 but not different from each other.

Treatments 2 and 7 not significantly different from 10 (control).

In respect to materials applied for the first generation, treatments 7, 8 and 9 were all similar, each receiving one application of BHC dust at the rate of 4.8 oz. BHC (90 per cent. gamma isomer) per acre. As compared with the controls, all plots in treatments 8 and 9 showed a marked reduction in attack. On one plot of treatment 7, 50 per cent. of the roots were infested but on the remaining three, the unattacked roots averaged 96.6 per cent. It appeared probable that the BHC dust was inadvertently omitted from this plot. The rate of BHC used in these treatments corresponded to approximately 2 lb. 4 oz. crude BHC per acre, a rate slightly lower than the minimum used in 1948 and 1949.

Treatment of the seed bed with BHC dust (treatments 5 and 6) gave in both cases a similar and high level of control, but even the lowest rate used corresponded to some 8 lb. per acre of crude BHC, a rate considerably higher than that which gave an imperfect control in 1949.

A high level of control was also given by the seed treatment involving the use of less than 1 oz. per acre of the 90 per cent. gamma BHC. Further data are required to confirm this performance.

The outstanding plots in this trial, however, were those of treatment 4. The foliage was more vigorous than on other plots, and bronzed and drooping leaves, the normal symptoms of carrot fly attack, were nowhere in evidence. Reflecting this condition, the roots were free from damage and tended also to be larger and more uniform in size and shape than on other plots. In treatment 3, where only a single application of T.V.O. + BHC spray had been used, the protection was less complete. Where T.V.O. alone had been used (treatment 2), no reduction in attack resulted and foliage symptoms of damage were as prominent as on the control plots.

Palatability tests were carried out in early August on samples taken from two replicate plots of each treatment. No evidence was obtained of tainting or of loss of carrot flavour with any treatment, neither were any oily or other flavours reported such as might have arisen from the use of T.V.O.

The carrots on these plots were allowed to remain in the soil until late October when they were re-sampled. This showed that a very severe second generation attack had occurred and that there was no significant difference in its intensity on any of the treatments. This failure of the May and June applications of BHC to exert an effect on the second generation of carrot fly in August and September contrasts sharply with the results obtained at Cambridge in 1948 and 1949, and also in 1950 (see opposite). The comparatively rapid disappearance of BHC from fen soil may well be due, however, to the high soil temperatures reached in the surface layers of black soil in summer causing greatly increased volatility of the BHC and hence considerably hastening its rate of loss. The experiments at Cambridge were carried out on a gravelly clay loam, which has a much lower heat absorbing capacity than black fen soil.

A replicated plot trial on early sown carrots was also carried out at Cambridge in 1950, the treatments being similar to those used in the parallel experiment at Mepal. Except in the case of the seed treatment, all the BHC materials were applied in May or June as for the control of the first generation. This infestation, however, was only slight but considerable damage caused by the second generation was recorded in January, 1951, the carrots from each plot having been separately clamped in November.

All the BHC treatments gave statistically significant reductions in the degree of infestation as compared with the controls, the attack on which was 42.8 per cent. The outstanding treatments were BHC dust, applied to the seed-bed at the rate of 17.8 oz. BHC (90 per cent. gamma) per acre which gave 96.0 per cent. unattacked roots and, secondly, BHC applied to the seed-bed at 12.3 oz. BHC per acre followed by a BHC+ T.V.O. atomised spray applying 5.0 oz. BHC per acre. This gave 95.4 per cent. unattacked roots. T.V.O. applied alone gave no improvement as compared with the

controls. Seed treatment with BHC, carried out as in the previous experiment, gave a significant reduction in attack. This infers that the low quantity of BHC, applied in March, was exerting a pronounced insecticidal effect in August and September, against the second generation of the pest.

A second replicated plot experiment using late (June) sown carrots was also carried out at Cambridge. Details of the treatments and of the results obtained are shown in Table III. The carrots were lifted and examined in November.

TABLE III

Control of the Second Generation of Carrot Fly on Late Sown Carrots, Cambridge, 1950

Treatment	Total weight of BHC (90% gamma isomer) applied oz.	Carrots unattacked %	Carrots attacked and unsaleable %
1. T.V.O. only, 1 application 1st August, 22 gals. per acre ...	nil	83.5	2.0
2. T.V.O.+BHC, 1 application 1st August, 23.5 gals. T.V.O./acre, 11.6 oz. BHC/acre ...	11.6	85.2	2.0
3. T.V.O.+BHC, 1st application 1st August, 25.0 gals. T.V.O./acre, 11.9 oz. BHC/acre. 2nd application 16th August, 34.8 gals. T.V.O./acre, 16.6 oz. BHC/acre	28.5	97.0	0
4. T.V.O.+BHC, 1 application 1st August, 25 gals. T.V.O./acre, 17.9 oz. BHC/acre	17.9	94.5	0.25
5. BHC dust to the rows. 1 application 1st August, 4.8 oz. BHC/acre	4.8	78.8	5.0
6. Untreated	nil	73.0	4.5

Treatments 3 and 4, both giving a high level of control, were the only treatments significantly better than the untreated. Tasting tests failed to show that the BHC had caused any tainting or loss of flavour and no contamination by oil was detected.

Discussion

Experiments carried out over the period 1945-1950 have shown that a very considerable degree of carrot fly control may be obtained with BHC. By applying the insecticide to the rows, the minimum quantity of crude BHC (isomeric mixture) which can be expected to give a substantial degree of control would appear to be about 4 lb. per acre. Against heavy infestations it might well be necessary to double this quantity. If this is done, however, the flavour of the carrot crop and probably that of certain subsequent root crops may well be adversely affected. The development of a high gamma BHC has meant, however, that the insecticidal effect formerly achieved with crude BHC may now be obtained with a much lower dosage of the high gamma material.

It has been shown that a high degree of carrot fly control can be obtained by applying 90 per cent. gamma BHC in several different ways. It may be applied to the rows either mixed with an inert dust or dissolved in a mineral oil, or it may be used as

a pre-sowing seed-bed treatment. Experimental evidence indicates that the most economical method of use, however, is to apply the BHC directly to the carrot seedlings and to the soil immediately adjoining the plants. Whether this may be most efficiently done by applying the insecticide in a dust or in oil cannot be stated from the data at present available. However, if the timing and method of application of an oil spray, primarily designed to control weeds, are found to meet the requirements necessary for the successful action of BHC or can be modified to do so, then the advantages from using a dual purpose oil spray may be decisive. Treatment of the seed with BHC also appears to show some promise for the control of carrot fly. The dosage which may be applied to the seed appears to be strictly limited, since phytocidal effects result from high dosages. At the rate used in these experiments, however, such effects were not shown and in one case where germination was somewhat delayed by poor soil conditions, an increase in plant population resulted.

The use of T.V.O. alone produced no measurable reduction in carrot fly attack. Cases where its use has apparently increased crop vigour would appear to be due in part to the elimination of weed competition and to its toxic effect on carrot aphids which may cause severe stunting of the crop.

SUMMARY

1. Experiments over the period 1945 to 1950 have shown that a high degree of carrot fly control may be obtained with benzene hexachloride (BHC).

2. When used as an isomeric mixture, the dosage of BHC required to give control may result in the contamination of the carrot crop.

3. When high dosages of an isomeric mixture are used, other root crops grown on the same land the following year may also be tainted.

4. With BHC of high gamma content in place of the isomeric mixture, the dosage may be greatly reduced and a good control obtained without tainting the crop.

5. High gamma materials would appear to be most effectively applied to the carrot seedlings along the rows, either in a dust or in a light mineral oil. Promising results have also been obtained with a high gamma BHC seed dressing.

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PEA APHID POPULATION STUDIES IN 1950

By J. A. DUNN

In 1948, an investigation was begun on the bionomics and control of the pea aphid *Acyrthosiphon pisum* Harris. This pest, though subject to periodical fluctuations, is often of major importance to pea growing in this country. Data obtained in 1950 bearing on this investigation are given below, together with a brief outline of the life-history of the pea aphid.

General Life History

In East Anglia, the pea aphid can be found on many leguminous plants. The more usual hosts, however, are peas, lucerne, hop trefoil, clovers and vetches.

Winter is passed almost exclusively in the egg stage. The eggs are laid on perennial and biennial legumes and most abundantly on the two *Medicago* species, lucerne and hop trefoil. The eggs hatch in late February or in March and the fundatrices which emerge give rise to another generation, also wingless, some five or six weeks later. These in turn produce a generation which contains some winged members.

The rate of development of the aphid increases rapidly as the temperature rises, so that the interval between the production of one generation and the next is soon reduced to about 12–14 days. Big populations of aphids are quickly built up on the overwintering host crops and more and more winged individuals are produced. During May and early June large numbers of these winged forms migrate to peas and other summer hosts where they breed rapidly and, if unchecked, cause damaging infestations. A back-migration from the summer to the winter hosts takes place in autumn. If the overwinter host crop is periodically cut during summer and autumn then the young plant growth produced is capable of maintaining high populations of the pea aphid throughout this period.

Reproduction from spring to autumn is entirely asexual and living young are produced but, in late autumn and early winter, true males and females occur and fertilised eggs are laid.

Pea aphid population studies in the field

Population studies of pea aphids have been made on both lucerne and hop trefoil for three consecutive years. Those on lucerne have been made throughout that period on the same field at Sawbridgeworth, Essex. The studies on hop trefoil, owing to the biennial nature of the crop, have been made on several fields on a farm at Hatfield Heath, Essex. Population data for the same three years have also been obtained from pea crops in the Essex area.

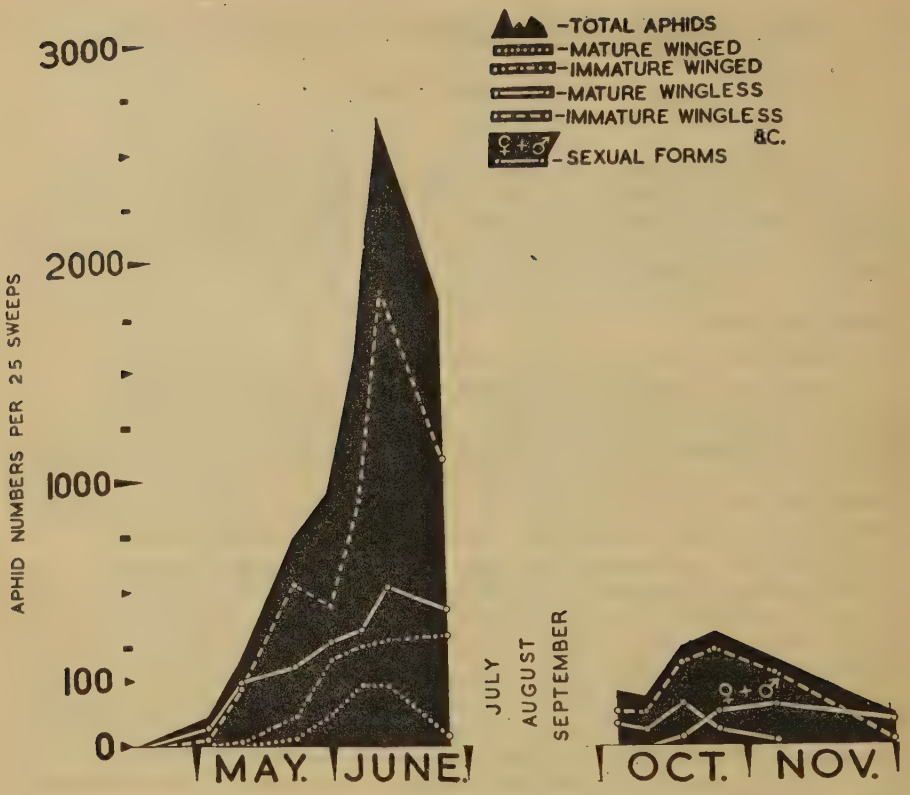
The populations on hop trefoil (*Medicago lupulina* L.)

A twenty-acre field of hop trefoil, at Hatfield Heath (Essex), used for population studies in 1950, had been undersown in 1949 and was scheduled to be cut for seed in 1950.

Samples were taken at intervals from an area of about one acre where the plant population was most uniform. Each sample consisted of 25 semi-circular sweeps made with a 12-inch net. Egg hatching began in early March but owing to the initial aphid numbers being very low, crop sampling was not begun until 3rd May.

The aphids taken in each sample were graded into :—

1. Mature winged
2. Immature winged
3. Mature wingless
4. Immature wingless.



The total of individuals taken and the composition of the population is shown in the graph. It will be seen that the springtime growth in numbers reached a peak on 13th June and that this was followed by a decline. The sampling could not be continued after 26th June owing to both net and samples being fouled by the mucus from an exceptional number of snails in the crop.

It was apparent, however, that the general decline continued until the time the crop was cut when the population had virtually disappeared. This decline was due partly to the departure of the winged forms but more to the maturing crop becoming progressively less suitable for aphid reproduction. Ladybird larvae too, substantially helped this decline in numbers.

The graph also shows the changes in numbers of the different types of individuals in the population. The mature apterous forms were most numerous initially but, as the reproduction rate increased, the immature stages soon outnumbered these. The winged forms, at first immature and a little later adult, began to appear in increasing numbers from about mid-May. All immature wingless and winged individuals below third instar were grouped together as no wing buds are evident in early developmental stages. This helped to swell the immature apterous category and the apparent drop in numbers in this group on 31st May was probably the result of an exaggerated count on 23rd May. The sample of the 23rd must have included many immature winged forms of the first generation in too small a condition to separate. Later, when the production of winged forms became a feature of the population, an equilibrium in the separation error was undoubtedly established and no such further drop occurred. Owing to the mobility of the mature alatae, the number of these recorded at the time of sampling must have been a somewhat uncertain estimate of the actual numbers

produced. Unsuitable migration weather causes a build up of alatae, whilst ideal migration weather causes their immediate departure. Thus, only the winged individuals present at the exact time of sampling figure in the count and no measure can be made of those which have migrated prior to sampling. The numbers of immature winged, however, with certain reservations due to mortality, give an estimate of the possible migration strength some few days later. Reference to the graph will show that the proportion of immature winged forms in the population was increasing up to the time when sampling was abandoned, whereas the wingless population, mature and immature, was decreasing. A continuation of sampling would have shown the immature winged forms (and hence subsequent adult numbers) to have achieved a majority and the apterous aphids to be rapidly disappearing.

The small graph to the right of the main figure represents data obtained from an adjacent field of hop trefoil undersown in 1950 and in its first year of growth. This graph shows the type of population found in the late autumn. The winged return migrants had effectively disappeared by the time sampling began and only a single individual was taken. A small peak in aphid numbers was reached on 25th October and the population on that date consisted chiefly of immature stages. The apterous non-sexual forms were disappearing, their place being taken by sexual forms. The males and oviparous females first appeared in the sample on 18th October and from that date the females predominated. The aphid samples in this field have been followed by egg counts, with a view to assessing the general build-up and subsequent survival of the overwintering egg population.

Insect enemies

In addition to assessing the aphid populations occurring on hop trefoil, a record was also kept of the natural enemies taken during sampling.

The most common predators were ladybirds, which occurred both as larvae and adults. In Table I, the numbers from 25 sweeps are given. In all cases the vast majority were *Coccinella septempunctata*. The adults reached a peak in early June whilst their progeny became very numerous at the end of June and early July. On 26th June the proportion of ladybird larvae to aphids was one to twenty which was sufficient to exert a considerable check on the aphid population.

TABLE I

Date	Ladybirds per 25 sweeps		Percentage parasitism
	adults	larvae	
3rd May	0	0	3
11th May	1	0	22
23rd May	9	0	15
31st May	8	0	22
7th June	12	2	22
13th June	1	19	18
26th June	0	93	no record

Syrphid larvae were first recorded on 26th June and appeared only in small numbers. They have not been included in the table.

The percentage parasitism was derived from a separate assessment, an additional collection of aphids being swept up on each occasion and kept alive in the laboratory until the degree of parasitism was evident. These figures were lower than in the previous year and it will be seen that parasitism remained almost constant from 11th May, with no obvious tendency towards a peak. The levels reached by parasitism were never such as to reduce severely the rate of aphid increase.

Populations on peas

In order to obtain an estimate of the aphid population on most pea crops, a different method of sampling has to be adopted from the sweeping method used on such crops as lucerne and trefoil. In the case of Maple peas, however, which are generally either broadcast or sown in six-inch drills, a tangled carpet of foliage results and the sweeping method of sampling can still be used. Where peas are sown in wide drill widths, however, as is the usual practice with crops grown for green picking and for seed, no sweeping method has been found to give a consistent estimate of the population. Such estimates appear to be best obtained by taking plant tips, each about two inches in length and including the growing point and enclosing leaves. Colonisation by the pea aphid first occurs in this region. The sample is obtained by removing tips at spaced intervals, whilst the sampler traverses the two diagonals of the selected area. The number of tips taken is 50 or 100 per plot according to the area involved. To prevent further aphid reproduction and to eliminate loss due to predator activity, the tip sample is injected with a small quantity of methyl iso-butyl ketone and placed in an airtight container. The sample with the insects, dead and relaxed, can then be dealt with later. In assessing heavy aphid populations where the foliage on the lower parts of the plant has become infested, individual whole plant samples are taken and the aphids killed and assessed as previously outlined.

Field observations on pea crops in 1950

The spring populations of pea aphid on overwinter host crops in 1950 were comparatively small owing to the surviving egg population being low. In addition, the cold spring restricted their rate of increase. Weather favourable for migration and for a subsequent population build-up on peas occurred in June and some growers of early pea crops resorted to insecticidal control measures. The July rains, however, severely reduced populations and the infestations were finally decimated by a fungal disease which followed. On later sown crops, heavy rains and fungal disease, supplemented by predators and to a much less extent by parasites, restricted aphid populations to very low numbers.

Population counts were made on certain pea fields in the Harlow and Hatfield Heath area of Essex. The first, shown in Table II, illustrates the composition of the population and growth in aphid numbers which took place during June on a field of Maple peas growing at Potter Street, Harlow.

TABLE II

Date	Total aphids per 25 sweeps	Alatae/25 sweeps		Apterae/25 sweeps	
		adults	young	adults	young
3rd June	139	8	0	72	59
7th June	685	11	6	334	313
13th June	879	8	8	477	386
26th June	6,552	37	881	2,834	2,800

From 13th June the population increased prodigiously, and in two weeks an infestation had developed which was causing considerable damage. More than 6,500 aphids per 25 sweeps were recorded on 26th June. Commercial control measures carried out a day later made it impossible to assess the combined effect of fungal disease and syrphid larvae. These two natural enemies were rapidly increasing and it was thought that if not actually checking the aphid population on 26th June they would soon have done so. As it was, fungal disease, syrphid larvae and rain accounted for most of the aphids which escaped chemical treatment. Table II shows that, between 13th and 26th June, there was a disproportionate increase in the number of young alatae ; they constituted less than one per cent. of the aphid total on the former date and more than seven per cent. on the latter.

Some data were also obtained on biological control agencies from a field of Onward peas growing adjacent to the field of hop trefoil at Hatfield Heath. Complete records of the growth of the aphid population were not collected but samples taken during the time of maximum aphid numbers, showed that the population reached a peak on 19th June, with a total of 2,216 aphids per 100 tips. The source of the aphid population was undoubtedly the adjacent winter host crop and it was expected that, in addition to aphids, the trefoil might also furnish a supply of attendant natural enemies. An examination, however, did not indicate that a transfer of predators and parasites had taken place sufficiently early to prevent the infestation of the pea crop by aphids.

A migration of *Coccinella septempunctata* on to the peas occurred, but it lagged behind the aphid migration by four or five weeks. The ladybirds which moved over were newly emerged adults of the hop trefoil generation and they swelled the numbers of ladybirds already present on the peas. The coccinellids helped to bring about a decline in the aphid population but syrphid larvae were of more importance in this connection. The origin of the latter was quite independent of the hop trefoil, for not only were the main species concerned different on the two crops, but they appeared on the pea crop and became abundant there well before they were first recorded on the hop trefoil.

Parasitism on the hop trefoil aphid population, as stated previously, was almost constant at about 20 per cent., from 11th May onwards. Samples taken on 26th June on the peas, however, at three distances parallel to the hop trefoil gave the following results :—

	parasitism %
Next to the hop trefoil	21
35 yards from the hop trefoil ..	13
70 yards from the hop trefoil ..	10

This would appear to indicate that the hop trefoil was the source of the parasites, but that the spread of the parasites from this source was not very rapid.

After the beginning of July, aphid populations on peas were suppressed by natural factors in most cases. The population figures recorded in September on a field of late sown Kelvedon Wonder peas and given in Table III, however, were of a much higher order than those found elsewhere. This might be explained by the noticeable absence of fungus-attacked specimens together with the small number of predators in this field.

Table III shows the percentage parasitism in addition to the total number of aphids and the number of syrphid larvae taken per 100 tips. Neither ladybird adults nor larvae were found.

TABLE III

Date	Aphids per 100 tips	Syrphid larvae per 100 tips	Percentage parasitism
6th September	690	2	15.5
12th September	2,620	7	22.0
19th September	460	16	16.0
27th September	39	7	6.0

A peak in aphid numbers was reached on 12th September. From that time the numbers fell rapidly, the change being brought about by rain and progressively colder weather.

DISCUSSION

The data given in this paper are supplementary to more extensive studies made on the pea aphid. A study of the composition, build-up and decline of pea aphid populations during spring, summer and autumn on hop trefoil together with similar data for peas gives a picture of the life history of this insect for the greater part of one particular year. The results from other years, however, have served to show how extremely variable the situation can be and that studies over several seasons are essential for a full understanding of the problem. The complex reasons for seasonal fluctuations are very poorly understood but are, nevertheless, of fundamental importance. An attempt is being made to investigate the natural factors which limit aphid growth and which combine in varying degree to produce these fluctuations. An appreciation of the relative importance of the factors in natural control may well enable predictions to be made on the probable fate of particular aphid infestations and thereby make possible an assessment of the need for chemical methods of control.

SUMMARY

1. The growth and decline of pea aphid numbers on a crop of hop trefoil are described.

2. The changes in composition which occurred within these populations showed that the development of winged aphids became increasingly important in June.

3. The most obvious feature of the aphid population in autumn was the progressive development of sexual forms, which accompanied the disappearance of the non-sexual types. The population changes on peas during the summer are also described.

4. Information collected on the natural enemies of the pea aphid showed that, on the pea crop in 1950, predators were of more importance than parasites in limiting the populations of this pest.

5. Data were obtained from an aphid infested pea crop showing that the dissemination of parasites over the field was not rapid.

6. Fungal disease was noted to be of importance in checking aphid numbers but unfavourable weather was of more direct consequence in this connection.

INVESTIGATIONS ON INSECTICIDAL DUSTS

By G. A. WHEATLEY

INTRODUCTION

In 1947, unsuccessful attempts were made to control pea aphids (*Acyrthosiphon pisum* Harris) with DDT dusts of similar specifications to those found to be satisfactory in the U.S.A. The dusts used contained 1 per cent., 2 per cent., and 4 per cent. w/w of DDT incorporated into a commercially available filler, whilst, in addition, some were impregnated with a non-volatile "oil," a process said to enhance their effectiveness. All the materials produced an incomplete control although weather conditions during application were good and the machine used was apparently very efficient.

The failure was attributed to either the method of incorporating the insecticide into the carrier or to the characteristics of the diluent itself; of both features there appeared to be a great paucity of knowledge. Studies were initiated, therefore, to determine as far as possible the characteristics which should be associated with insecticidal dusts from the viewpoint of *ground application in the field.*

At the outset of the work in October, 1948, a survey of the relevant biological literature showed that much of the previous work attempting to analyse the factors affecting the performance of dusts was somewhat inconclusive and the results, in certain cases, were open to interpretations other than those drawn. It was apparent that, for a greater understanding of the factors influencing the efficiency of ground-crop dusting with insecticides, further fundamental work was required.

The problem may be divided conveniently into two main groups of factors; first, those which are concerned in getting the insecticide into contact with the insect pest, and secondly, those factors which relate to the specific toxicity of the dust particles to the insect once contact has been established (1).

The former, or more mechanical, side of the problem involves the study of the physical and, to a lesser extent, the chemical properties of dusts (*sens. lat.*). The design of the dusting machine is important for the production of a good dust-cloud but it is also essential that the physical nature of the dust should be suitable so that it is capable of being readily dispersed into a cloud in which aggregation of particles is at a minimum.

A superficial examination of a sample of dust could be expected to reveal only a rough indication of three physical characteristics, namely :—

(a) Colour—quite unimportant though often the most striking
(b) Bulk Density—whether a dust is "heavy" or "light"
(c) Flowability or Fluidity—the tendency to "ball-up" and "bridge".

Such features are merely the visible effects of the interaction of numerous empirical, physical properties. For example, bulk density depends on the individual effects of particle size range, particle shape, specific gravity of the material, porosity of particles, and moisture content, together with the nature and the amount of toxic ingredient present. The flowability of dusts is affected by the same properties and also by the inherent chemical structure and the electrostatic properties of the components of the dust mixture. Mineral diluents differ widely in abrasive qualities and, in general, it may be said that, in order to keep down wear to mixing and dusting machinery, the abrasive tendency should be as low as possible without affecting insecticidal efficiency. The deposit of an insecticide should adhere tenaciously to plant foliage in order to give prolonged protection to a crop against an insect pest, and one of the drawbacks

to a wider use of dusting is that dust deposits, as a rule, do not "weather" as well as do deposits obtained from wet sprays. At present, the problem of "weathering" and the *modus operandi* of adhesion of particulate material to plant surfaces is very imperfectly understood.

Turning to the biological aspects of the problem, it appears that the manifested property of toxicity of dust deposits to insects is dependent, once again, on the interaction of several basic factors. These include particle-size deposited, distribution of particles over the plant surface, the type of "inert" diluent used, the effect of the method of mixing the "inert" and toxic materials, and the environmental conditions during and after the time of application. Furthermore, as different species (and even stages of the same species) of insects often differ widely in their susceptibilities to poisons, results obtained with one insect cannot be translated reliably to another species or type of insect without carrying out confirmatory tests.

The relative toxicities of dust deposits to a given insect can only be determined in the laboratory by means of a biological assay, whereby the insects are exposed to deposits under carefully controlled and repeatable environmental conditions. Much information can be obtained from such results using orthodox statistical methods and it is usually necessary to carry out field trials only with the more promising materials.

In the two sections which follow, the problem of particle size is discussed and the results of a field trial carried out in Essex are reported.

Work is continuing in the laboratory on the influences of particle size of inert diluents and of methods of formulation on the toxicity of insecticidal dusts. A biological assay technique has been devised for assessing the relative effectiveness of the materials using the pea aphid as test insect.

Notes on the Particle-size of Insecticidal Dusts

The literature relating to the measurement of particle-size range in fine powders is very extensive and, in itself, provides ample evidence of the difficulties associated with the problem. Insecticidal dusts are comprised largely of individual particles small enough to pass through the finest sieve meshes and hence fall into what is usually termed the "sub-sieve range" of particle size. Since the shape of the discreet particles is usually quite irregular, an absolute measurement of size cannot be readily made ; it becomes necessary, therefore, to resort to indirect methods of determining this property. As a result considerable confusion exists concerning the method of measuring and expressing the size of particles in insecticidal dusts.

Opinion appears to be unanimous that designation of a powder merely by a statement of the percentage by weight passing through a finely-meshed sieve (*e.g.*, 99 per cent. through a 300 B.S.S.) is inadequate in that it affords no data on the all-important size distribution of the material passing the mesh. Of the remaining designations, we may distinguish three main principles on which the figures are based. First, particle-size is often expressed by figures derived from direct microscope measurements ; with such data it is difficult to relate different powders one to another owing to the dependency of the method on particle shape. A second type of measurement employs the principle of determining the overall surface area of a powder by either the air permeation or the light-extinction methods. Again, no indication of the particle-size distribution is obtained from the single designation of the specific surface of a powder. Thirdly, there are the various sedimentation and elutriation methods of obtaining a size/weight distribution following the application of Stokes Law, whereby a small sphere falling under the action of gravity through a viscous medium ultimately reaches a constant (terminal) velocity (v) according to the relationship

$$v = \frac{2g\,r^2\,(d_1 - d_2)}{9\eta} \text{ cm./sec.}$$

where r=radius of sphere, d_1=density of sphere, d_2=density of medium, η=coefficient of viscosity of the medium, g=vertical acceleration due to gravity. Thus, if the terminal velocity of a particle is determined experimentally, the radius of an equivalent sphere is calculable since

$$r = \sqrt{\frac{9\eta\, v}{2g\,(d_1 - d_2)}} \text{ cm.}$$

Particle-size distribution in terms of Stokes Diameters are probably the most useful designation for comparing powders used for insecticidal dusts from the viewpoint of problems associated with deposition. Of the methods available for obtaining such results, elutriation using air as the fluid medium has been adopted for the present work in order to approach as closely as possible to conditions of field usage, and also to avoid what might prove undesirable effects were a liquid elutriation or sedimentation medium used. It would seem that data obtained by air elutriation would give some indication of relative reactions of dusts to an air-stream and it may be that dusts of similar reactions tend to deposit in a like manner, other factors being equal.

With this principle in mind, an air elutriator has been constructed so that dusts may be broken down into a series of fractions each of restricted size range, whilst, at the same time, it is possible to obtain some indication of size distribution in terms of Stokes Diameters. Air is bubbled into the bottom of a conical container to the top of which is fitted a long, wide-bore, vertical glass tube. The air passes up this fractionation tube and is led into a flask in which the dust particles are filtered out. A manometer has been arranged to record the volume of air per minute coming out of the exit tube from the flask and thus the velocity in the fractionation tube is calculable. By holding the velocity constant, the maximum size of particle carried up the tube is, at least for practical purposes, one with terminal velocity downwards slightly less than the upward air velocity ; *i.e.*, by substituting in the above formula and using the known air velocity in place of the terminal velocity (v) of the particle, the size of an equivalent sphere which will just *not* be carried over is determined. Thus, using a flaky talc diluent of density d_1=2.69 gm./c.c. and with a mean air velocity in the fractionating tube v=1.73 cm./sec., the coefficient of viscosity for air $\eta = 1808 \times 10^{-7}$ poises at 20°C. the density of air $d_2 = 1.203 \times 10^{-3}$ gm./c.c. at 760 mm. Hg and 20°C., and acceleration due to gravity g=981 cm./sec./sec., substituting in the above equation shows that the radius of an equivalent sphere which has a terminal velocity of fall equal to the upward air velocity of 1.73 cm./sec. is 7.305×10^{-4} cm., or, to use the more popular notation, 7.305 μ. The Stokes Diameter (Ds) of the largest particle which could possibly be carried over may be taken for practical purposes as Ds=2r=14μ (the accuracy is insufficient to warrant decimals of a micron).

Beginning with a low air velocity, the finest particles are removed from the parent material first The velocity is then increased by an amount sufficient to extract the next desired size range from the residual material left after the "fines" have been removed. This is repeated until a complete series of fractions has been obtained from the parent material ; such a series is shown in the analysis given in Table I which represents typical results obtained with the apparatus.

TABLE I

Fractionation Analysis of a 4% DDT/Talc Dust

Fraction Range (Ds)	% by Wt.
< 10μ	24.62
10μ — 14μ	12.43
14μ — 22μ	19.92
22μ — 32μ	21.02
> 32μ	22.01

Interesting observations on such a series of fractions can be made. A marked darkening in colour is associated with increase in particle size of a fraction, thus, the $< 10\mu$ range is almost white whilst the $> 32\mu$ range is considerably darker than the parent material. The particle size also affects bulk density as is shown in Table II, and since the flowability of a powder is altered by changing its bulk density, the fractions could be seen to become increasingly flowable in passing from the finest to the coarsest material. Indeed, the finest fraction of the DDT/Talc dust is extremely sticky and would prove very difficult to apply in the field whereas the coarser fractions are all of considerably better flowability than the original parent material which, in itself, is above the average with regard to this property.

TABLE II

Relation of bulk density to particle-size in a 4% DDT/Talc dust

Size Range of Fraction (Ds)	Bulk Density in gm./c.c.
Parent dust	0.87
$< 10\mu$	0.65
$< 14\mu$	0.67
14μ — 22μ	0.97
22μ — 32μ	1.06
$> 32\mu$	1.33

The presence of a relatively small quantity of very fine material (-10μ) in a coarser fraction results in a marked decrease in both bulk density and flowability of that fraction. A similar quantity of a coarse dust, however, when added to finer material appears to produce very little change in these physical properties. This is in keeping with the observations of Gooden (2) and evidence seems to be increasing that the amount of "fines" present probably plays a large part in influencing the physical properties on insecticidal dusts.

It is certain that in order to improve the efficiency of crop dusting, more attention will have to be paid to this question of the effect of particle-size on the performance of insecticidal dusts in the field from both physical and biological standpoints.

A Field Trial of DDT Dusts against Pea Aphids (*Acyrthosiphon pisum* Harris)

The experiment was carried out on part of a four-acre strip of Onward peas near Hatfield Heath, Essex, during the last two weeks of June, 1950.

The Crop

The peas were bounded on three sides by hedgerows and on the fourth side by a crop of hop trefoil (*Medicago lupulina* L.). At the time of treatment the peas, planted in 22-inch rows, were approximately 15 inches high and just coming into first flower. Apart from a certain amount of damage wrought by the aphids, the plants were apparently very healthy and the stand was quite even over most of the area.

Experimental Layout

A plot size of 10×10 yds. (16 rows wide) representing 1/48.4 acres was chosen as a convenient working unit. The layout was in five randomised blocks with seven plots per block. Around each plot a neutral area approximately 1.5 yds. wide was left untreated to minimise drift and edge effects from plot to plot.

Aphid Sampling Techniques

The distribution of the pea aphid over the host plant is such that they may be confined almost entirely to the "tips" or growing points of the pea or may be spread

additionally in varying proportions throughout the foliage. Sampling of the "tips" was performed by carefully pinching off 30 "tips" per plot following a prearranged system, placing them in paper bags which were sealed and immediately injected with a small quantity of methyl iso-butyl ketone (3) before removing to the laboratory to be counted. This sampling was done immediately before treatment and three days and seven days after treatment. At the time of the final sampling, seven days after treatment, a further series of ten whole-plant (minus "tips") samples were obtained from each plot by cutting off the plants just above soil level, shaking them into a large tin, from which the aphids were collected and treated with the ketone as previously.

Preparation of the DDT Dusts

The treatments were designed to obtain certain information on the mixing of DDT dusts by the method of impregnation with a volatile solvent. A special laboratory ribbon-mill was used to prepare the dusts. The DDT was dissolved in a slight excess of commercial benzene and the solution atomised under a pressure of 30 lb./sq. in. into the talc diluent which was under constant agitation in the mill throughout. The mixed dusts were then spread out to allow the benzene to evaporate and leave the DDT intimately mixed with the carrier. In order to break up possible particle aggregates resulting from the impregnation process and to ensure evenness of distribution of the DDT, the dust was brushed through a 100 B.S. sieve before use. A technical grade of DDT, said to contain approximately 80 per cent. by weight of the p,p-isomer, was used throughout; the diluent employed was of the "flaky" talc variety. In addition to the impregnated dusts, a 4 per cent. DDT/Talc dust was prepared by the orthodox method of ball-milling for approximately four hours and was included in the treatments for comparative purposes.

Dusting Machine

A "Vemorel" knapsack duster was found to be the most suitable form of machine for such small-plot experiments. Providing that a minimum "head" of dust was maintained in the container, a reasonably even dust cloud was produced and a very adequate penetration and deposition of dust was possible by treating each row separately. By checking the operation time for each row a fairly constant dosage rate was obtained from plot to plot.

Treatments

Treatment	Dosage applied
A. ½% DDT/Talc, Impregnated mixture ...	81.6 lb./acre
B. 1% DDT/Talc, Impregnated mixture ...	62.1 lb./acre
C. Control—Untreated	nil
D. 2% DDT/Talc, Impregnated mixture ...	66.5 lb./acre
E. Control—Untreated	nil
F. 4% DDT/Talc, Dry-ground mixture ...	69.5 lb./acre
G. 4% DDT/Talc, Impregnated mixture ...	67.3 lb./acre

The inclusion of two untreated control plots provided an indication of reliability of the newly devised sampling technique and was considered to be desirable on account of the variation in the aphid population across the experimental area. The dosage rate at which the various treatments were applied will be seen to be rather higher than the usual commercial dosage of 35-50 lb./acre. It is found that for small areas a rather higher dosage has to be applied to obtain an even cover owing to the lower efficiency of hand dusting machines and it is also probable that the wastage factor is greater than would be the case for large-scale treatment. For these reasons the results must be interpreted in *relative* terms only and not as absolute figures directly implying the degree of commercial control of pea aphids possible with the respective formulations.

TABLE III

The total number of aphids per 150 "tips" and the percentage reductions in population effected by the various treatments.

Treatments	Pre-treatment Aphids per 150 tips	3 days after treatment		7 days after treatment	
		Aphids per 150 tips	% reduction in population	Aphids per 150 tips	% reduction in population
½% Impregnated	3,912	886	68.0	194	86.6
1% Impregnated	4,448	723	77.0	89	94.6
Control	5,764	4,238	+4.0*	2,220	+3.9*
2% Impregnated	4,652	548	83.3	142	91.8
Control	4,170	2,786	5.5	1,462	5.4
4% Dry Ground	4,287	795	73.8	211	86.7
4% Impregnated	5,239	563	84.8	76	96.1

*Due to the use of the mean of the two control results ; one control must obviously have a population in excess of this mean.

TABLE IV

The total number of aphids per 50 plants (excluding "tips") sampled 7 days after treatment and the same expressed as simple percentage of the mean of the controls.

Treatment	Aphids per 50 plants	% of Control population
½% Impregnated	83	6.0
1% Impregnated	50	3.6
Control	1,511	109.1
2% Impregnated	49	3.5
Control	1,260	90.9
4% Dry Ground	87	6.3
4% Impregnated	55	4.0

Environmental Conditions

During the period of application, conditions were apparently very favourable with wind velocity 1–4 m.p.h. at crop height, an air temperature 66–68°F., and humidity 62–75 per cent. R.H. On the second and third days after treatment a fairly heavy rainfall occurred but for the remaining period the weather was overcast and dry.

Results

The aphid counts given in Tables III and IV represent the totals for each treatment, *i.e.*, in $5 \times 30 = 150$ "tips" and $5 \times 10 = 50$ plants respectively. The percentage reductions in populations in Table III are calculated using the formula of Abbot (4) which allows for the falling off of the control populations due to natural trend. If X = percentage living in the control plot, and Y = percentage living in the treated plot, then $100 \times (X—Y)/X$ = percentage reduction in population brought about by the treatment. The whole-plant samples, taken only at the final sampling seven days after treatment, indicate the relative state of affairs existing at that time; no allowance can be made for the population trend during the experiment and the figures in Table IV are expressed as simple percentages of the mean population on the two control plots.

DISCUSSION

It is seen from the figures representing the populations on the control plots that the natural trend of the insects was a decrease in numbers during the week of the experiment. This was evidenced also from general observations on the remainder of the field and it appeared that the treatments had been applied when the aphid population was at or near its peak. The constant population ratio between the two series of control plots appears to indicate that the sampling techniques were reliable.

An eightfold increase in concentration of the impregnated dusts, covering the range of 0.5–4 per cent. active principle, did not result in any marked improvement in toxicity. Such results indicate that there would be little to choose between the 1, 2 and 4 per cent. impregnated mixes and that these materials would produce a better control than the orthodox 4 per cent. dry ground mixed dust. The 0.5 per cent. impregnated dust was of similar performance to the 4 per cent. dry ground mixture.

These results confirm certain preliminary laboratory findings concerning the relative toxicities of the two types of mixes. An 0.5 per cent. impregnated dust was found to be approximately four times more toxic w/w than a 4 per cent. ball-milled dust. However, Anderson and Brooks (5), during their field experiments for the control of pea aphids in Eastern Virginia, found that an impregnated DDT dust prepared by use of a volatile solvent (in this case carbon tetrachloride) was only of similar toxicity to that of a ball-milled dust, both at 1 per cent. concentration of DDT. It is possible that the respective methods of mixing or the actual materials used may account for this difference in results. Little is known of the effect of mixing methods on the final toxicity of insecticidal dusts and it is hoped that more information on this aspect will be forthcoming later in the present researches.

SUMMARY

1. The principal factors governing the efficiency of insecticidal dusts are enumerated and discussed.

2. At present, considerable confusion appears to exist on the question of particle-size measurement of insecticidal dusts. The most useful designation of size-range is probably given in terms of equivalent Stokes' Diameters.

3. A brief description is given of an air elutriator for the separation of dust particles into a range of sizes, together with an example of size-range analysis with the apparatus.

4. With successive increase of particle size, colour deepens and bulk density and flowability increase.

5. A field trial confirmed laboratory findings that 1, 2 and 4 per cent. DDT dusts prepared by volatile solvent impregnation were of greater toxicity to the pea aphid than was a 4 per cent. ball-milled dust of orthodox type. A 0.5 per cent. impregnated dust had an effect similar to a 4 per cent. ball-milled dust.

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THE POSSIBILITY OF PRODUCING SEED OF CERTAIN VARIETIES OF SUMMER LETTUCE IN THE UNITED KINGDOM

By E. J. WINTER

INTRODUCTION

Experiments were begun in April, 1949, with the object of finding a method of producing summer lettuce seed in this country. Such a technique would be of great value to breeders and might even be applicable to commercial seed production. Of the five varieties examined, seed of Lobjoit's Green Cos and All-the-Year-Round is normally produced in France, while that of White Boston, Webb's Wonderful and New York is raised in America. Late bolting is a desirable character common to all these varieties and under United Kingdom conditions they do not flower early enough in the season to enable the seeds to ripen before the weather deteriorates in the autumn.

In attempting to discover environmental factors which accelerate flowering it is essential to avoid unconscious selection of plants which happen to be early bolters for genetical reasons. Seed from such plants would give strains which would obviously be unsuitable for lettuce production.

The effects of vernalisation, temperature, varying photoperiod and nitrogen/potash status have all been examined. No variant of any of these factors has given satisfactory results alone, but it seems likely that a combination of suitable levels of several factors may form the basis of a practicable method of seed production.

EXPERIMENTS ON SEPARATE FACTORS

Vernalisation

The flowering of many plants, including lettuce, may be accelerated if the germinated seeds are subjected to a period of low temperature before sowing (vernalisation). In order to discover the effect of duration and temperature of vernalisation on the above-mentioned five varieties of summer lettuce, experiments of factorial design were carried out in 1949 and 1950.

Two controls were used. Seeds of the first (C1) were germinated on the same date as the seeds vernalised for the longest time but, of course, had an extra period of normal growing conditions equal to the longest duration of vernalisation.

The second set of controls (C2) were germinated when all the vernalisation treatments had been completed. They, therefore, had the same period of normal growing conditions as all the vernalised plants, but were younger (as measured in days from germination) by a period equal to the period of vernalisation.

In the 1949 experiment, the seeds were germinated and vernalised on wet filter paper, but in all subsequent work the following technique was used. The dry seeds were first shaken with one per cent. by weight of "Spergon" (tetrachloro-para-benzoquinone). Tests showed that pre-treatment with this substance prevented attack by *Botrytis* during vernalisation, but had no effect on the growth rate of radicles of treated seeds. After treatment the seeds were spaced on sterile, graded sand of standardised moisture content, in closed petri dishes. The seeds were allowed to germinate for a given number of hours at a standard room temperature. The dishes were then transferred to a specially modified refrigerator where they remained undisturbed for the desired period of vernalisation. The vernalised seedlings were grown on to maturity by ordinary commercial methods.

The weather in 1949 was very favourable for seed production and all treatments (including controls) set seed. The summer of 1950 was abnormally wet and although

the effect of vernalisation was apparent in dates of hearting and bolting, all the plants succumbed to tipburn, *Botrytis*, or mildew before any seeds ripened. Varieties Lobjoit's Green Cos and All-the-Year-Round showed the greatest response to vernalisation. New York, Webb's Wonderful and White Boston responded to a lesser degree. Seed production in Webb's Wonderful and New York was found to be especially difficult because of the well-known susceptibility of these varieties to tipburn, *Botrytis* and mildew. Some vernalisation effects differed quantitively in the two years. In such cases conclusions were drawn from the 1950 figures because from the statistical point of view the 1950 experiment was better designed and had more replications. Moreover the 1950 weather conditions were nearer average and more experience had been gained in technique by that time. A typical result is shown in Fig. 1.

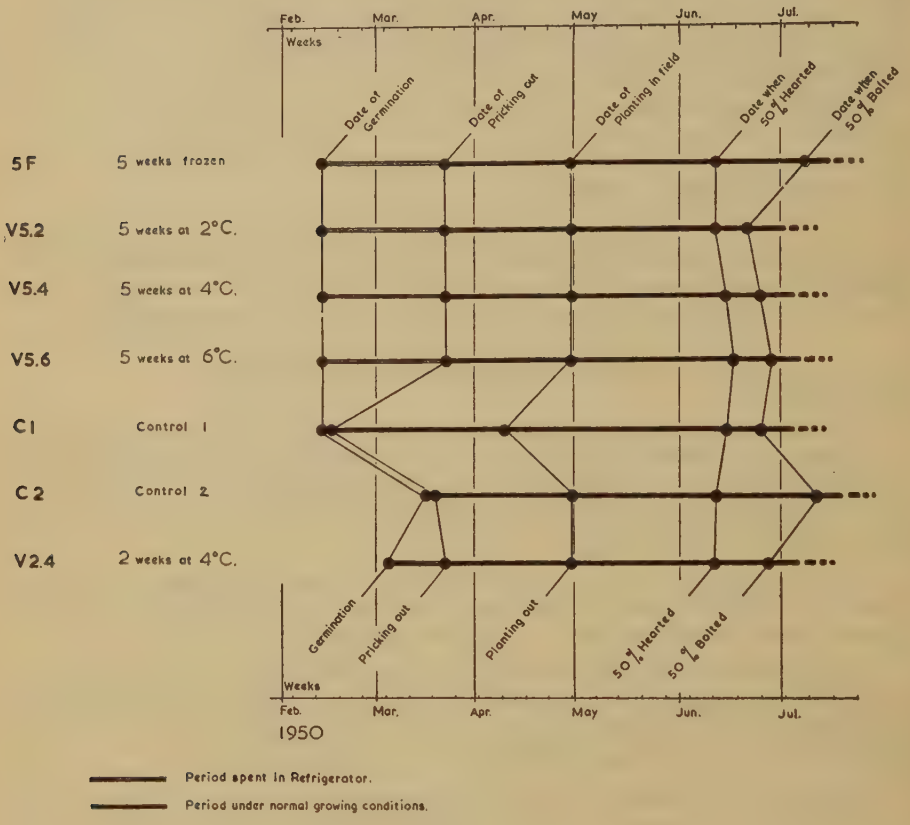

Fig. 1

Dates of stages in the life history (viz. germination, pricking-out, planting-out in the field, hearting and bolting) of plants given the following treaments:—

5F=five weeks below-zero "vernalisation".
V5/2=five weeks vernalisation at 2° C.
V5/4=five weeks vernalisation at 4° C.
V5/6=five weeks vernalisation at 6° C.
C2=controls germinated on the day vernalisation ended.
C1=controls germinated on the day the longest vernalisation treatment began.
V2/4=two weeks vernalisation at 4° C.

It will be seen that all the vernalised plants bolted about thirteen days before the C2 controls (germinated on the day vernalisation ended). There was no difference between the date of bolting of vernalised plants and that of the C1 controls (germinated on the day the longest vernalisation treatment began) although the C1 plants had spent an additional sixteen days in the greenhouse and 21 days more in the field, *i.e.*, C1 controls had 37 days longer under growing conditions than treatment V5/4, yet both bolted on the same date.

There was little difference between bolting dates of plants which had been given different periods of vernalisation. Apparently the variety All-the-Year-Round could be completely vernalised in about fourteen days. The lower the temperature of vernalisation, the sooner bolting occurred but the difference between the extremes (2° C. and 6° C.) was less than a week. If, however, "vernalisation" was carried out *below* freezing point, bolting was retarded instead of accelerated. This phenomenon is discussed on page 38. It was nevertheless desirable to vernalise at the lowest temperature which would give the desired result, in order to prevent the radicles growing so long that pricking out became difficult. The growth rate of radicles at low temperature was examined in detail and the results are presented in graphic form in Fig. 2, page 39.

An advantage of vernalisation was that it enabled the early part of the life of the plant to be spent in the refrigerator instead of in the field, without the date of bolting being affected. C1 control plants were placed in the field on 10th April and grew satisfactorily. If vernalised plants had been planted in the field on that date, it seems reasonable to suppose that bolting would have occurred about the end of May and thus three summer months would have been left for maturation of the seeds. Future experiments should be designed so that vernalisation is completed by the earliest date on which the weather permits planting out of the seedlings. It will be essential, however, to grow the vernalised plants under suitable conditions of temperature, day-length, and nitrogen/potassium nutrition, all of which factors have been shown to affect date of bolting (see later sections).

Photoperiod

Some strains of lettuce may be regarded as short-day plants, while others flower when the days are long. In 1949 and 1950, summer lettuce was grown in seven-hour days. The plants in the field were covered with plugged ten-inch pots for seventeen hours daily. In the greenhouse, potted plants were darkened by means of collapsible wooden boxes. Temperature and humidity inside the dark chambers were much higher than outside and, in consequence, many plants were killed by fungi. Statistical analysis of the results was thereby rendered impossible.

The first visible response to short days was twisting of the petioles so that the leaves became contorted. The stems of the plants then elongated but the leaves remained vegetative in character, and quite different from the small olive-green leaves which were characteristic of the normal bolting axis. Eventually a few bolting-type leaves were produced, followed by flowers in a few instances. It would appear that this elongation of the axis induced by short-day treatment was a form of etiolation as distinct from true bolting associated with flowering.

On 22nd December, 1949, young self-sown plants were lifted from the field and potted. Some were kept in the window of a plant room at a mean temperature of about 18° C. Control plants were kept on the window-sill outside and hence at a lower temperature although they received the same natural short day-length. The plants kept at the higher temperature produced twisted leaves and elongated axes similar to those of the plants given artificial short days in the summer experiments. The control plants remained dormant until spring.

At the end of March, both sets of plants were transferred to a cold greenhouse where those which had overwintered in the comparatively high temperature of the plant room, soon produced typical small, dark green bolting-type leaves, followed by

flowers. Seeds were harvested on 20th June. The controls, on the other hand, hearted first and then bolted normally about a month later; their seeds were not mature until 11th July.

These observations indicate that short-day treatment must be accompanied by relatively high temperature in order to be effective in accelerating bolting. Summer lettuce normally flowers when the natural day-length is long. It may be, however, that this flowering is not a result of the photoperiod but is caused by an entirely different factor which happens to operate in summer. Further experiments are necessary to decide this point.

Nitrogen/potassium status

All-the-Year-Round lettuce was grown in sand culture at three levels of nitrogen (N1, N2 and N3), combined with two levels of potassium (K1 and K2) in a factorial experiment with six replications. Throughout the experiment the plants given treatments N3K2 (*i.e.*, high nitrogen with high potassium), N2K1 and N2K2, were ahead of the others in stage of growth, size, and quantity of flowers. The plants given N1K1, N1K2 and N3K1 treatments were at least a week behind the others in general development. The amount of seed produced was the same for all treatments except N2K2 which gave 80 per cent. of the general mean, and N3K1 which gave only 40 per cent. of the mean. The seed of plants given the last-named treatment (high nitrogen with low potassium) was shrivelled and incapable of germination. These observations on the effect of high nitrogen with low potassium status corroborate unpublished results obtained by the writer using *Lemna minor*. In the presence of a high level of potassium a plant can utilise a high level of nitrogen which would be toxic at low potassium status.

The results of this experiment indicate that in order to obtain early flowers and seeds, All-the-Year-Round Lettuce should be given liberal applications of both nitrogen and potassium.

The author wishes to acknowledge the help and advice given by Dr. E. J. Hewitt of Long Ashton Research Station in connection with the sand culture technique.

Below-Zero "Vernalisation"

Vernalisation experiments in 1949 and 1950 included treatments in which the "vernalisation" was carried out below 0° C. This treatment had the opposite effect to vernalisation above freezing point, *i.e.*, bolting was retarded usually by about two weeks. (Standard Error = $\pm$1.34 days.) The resultant seedlings were noticeably tougher to handle and appeared greener in the field. There were indications that the diameters of the hearts of treated plants were greater than those of untreated plants. These observations afforded some confirmation of the work of Rudorf and Stelzner (1) who recorded increase in fresh weight and market value as a result of "vernalisation" at $-5°$ C.

These results suggest that below-zero "vernalisation" might prove to be of some value in commercial lettuce production. The treatment could be carried out in a suitably adjusted domestic refrigerator. Since the growth of the radicle at or below zero is virtually nil, there would be no difficulty in sowing the treated seeds by ordinary commercial methods.

Miscellaneous

Other facts established during the course of these experiments are briefly stated below.

When vernalising seedlings, it is desirable to minimise growth of the radicles in order to avoid difficulties at the time of sowing the vernalised seeds in soil. The growth rates of All-the-Year-Round radicles at various vernalising temperatures are shown in Fig. 2.

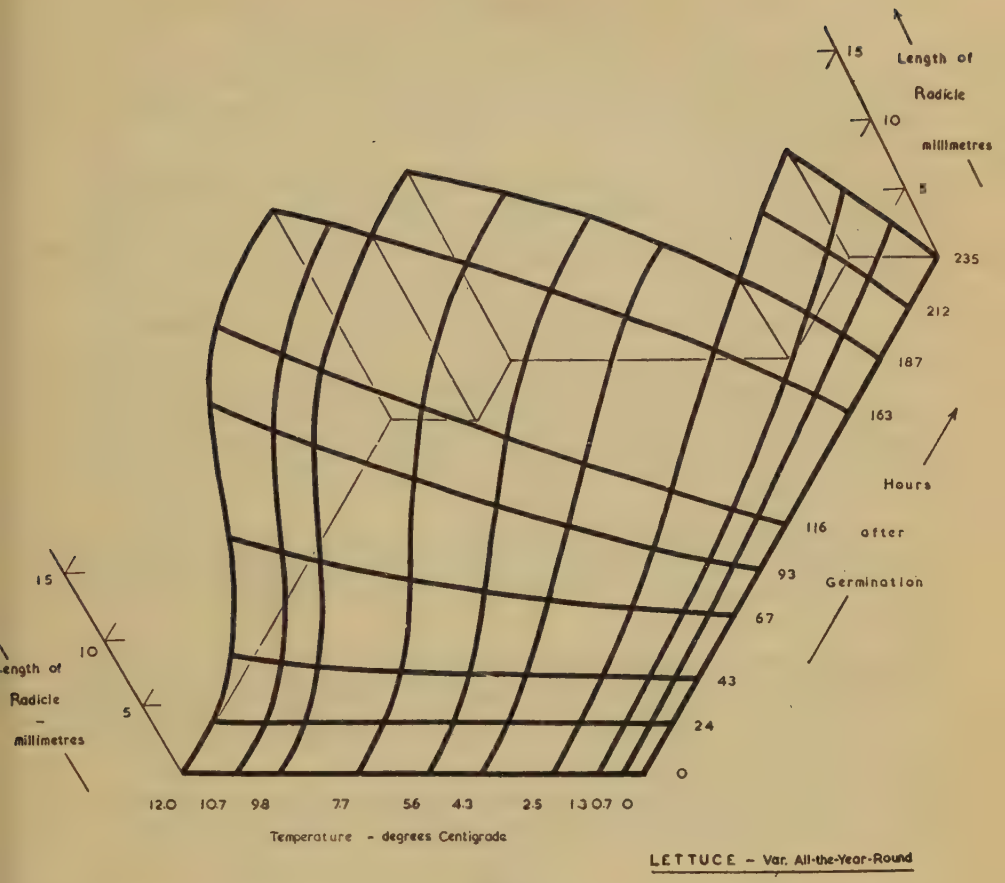

Fig. 2

Length of radicle of All-the-Year-Round lettuce at various temperatures and times after original imbibition of seed.

Vernalisation did not affect the growth rate of radicles at room temperature, nor the growth rate of the bolting axes of mature plants in the field.

Most of the vernalised plants bolted by elongation of the main axis into a single inflorescence. Normal plants usually bolted simultaneously from a number of axils so that several inflorescences appeared on one plant.

Attempts to distinguish between vernalised and unvernalised growing points by variations of the microscopical staining method of Bassarskaja and Grossmann (2) were not successful.

Lettuce seeds imbibed and kept at 30° C. did not germinate. When the temperature was reduced to 26° C., some individuals germinated, others remained dormant and the remainder were found to be dead.

When newly germinated lettuce seeds were frozen, the severity of damage depended on the length of the radicle. If the radicle was longer than about 5 mm. it was killed. On thawing, adventitious roots appeared from the region of the hypocotyl. If the radicle was shorter than 5 mm., freezing discoloured it but, on thawing, the root tip grew through the discoloured portion and no adventitious roots were produced at that stage.

SUMMARY

1. Experiments have been conducted over two seasons with the object of finding a method of producing summer lettuce seed in the United Kingdom. While various treatments have given promising results, further work will be necessary before a method can be recommended.

2. Vernalised plants bolted about thirteen days sooner than unvernalised plants grown from seeds germinated on the day vernalisation ended.

3. Vernalised plants bolted at the same time as unvernalised plants sown on the day vernalisation began.

4. "Vernalising" below freezing point retarded the date of bolting by about two weeks.

5. Quantitative observations were made on the effect of nitrogen-potassium status on bolting and seed production. High nitrogen with high potassium, medium nitrogen with high potassium, and medium nitrogen with low potassium caused early bolting. High nitrogen with low potassium caused late bolting and the production of poor shrivelled seed.

6. The elongated axis produced in response to short days was observed to differ morphologically from the normal bolting axis. There were indications that, to be effective in accelerating bolting, short day treatment must be combined with relatively high growing temperature.

7. Measurements were made of growth rates of radicles at various vernalising temperatures, and of growth rates of bolting axes of vernalised and unvernalised plants.

8. Attempts to distinguish between vernalised and unvernalised growing points by staining methods were not successful.

9. The effect of relatively high temperature (30° C.) and of low temperature (below freezing point) on imbibed and germinated lettuce seeds was studied.

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THE GERMINATION OF CHELTENHAM GREENLEAVED BEET

By E. J. WINTER

The poor germination of "seed"* of many commercial lots of Cheltenham Greenleaved Beet has been causing concern to seedsmen and growers alike. An immediate solution to the problem would be to cultivate a different variety without this defect, but this is unacceptable to the seed trade because of the popularity of Cheltenham beet with the market growers.

Among seedsmen and growers, opinion is divided as to the cause of the poor germination. Some consider that it is the result of delay in threshing the crop. Dry weather before cutting, or wet weather afterwards are each blamed, but many cases are known of batches of bad "seed" which have definitely not been rained upon while in stook. The opinion has been expressed that when the yield of "seed" is high, its germination is also high. If, however, the seed crop is grown under rich conditions, it is said to grow "wild" and lose character.

At present there is no conclusive evidence to show whether the cause of the poor germination is genetical or environmental, or both, and preliminary experiments have been designed to clarify the nature of the problem.

Observations

Thirty-three samples of Cheltenham Beet "seed" were kindly provided by nine representative firms, together with two samples of Detroit Globe and one of Bell's Non-Bleeding for comparison.

Various germination tests were applied including the standard method (embedding the fruits in the surface of damp sand) and burial at various depths in wet sand. The effect of low temperature during germination tests was also studied.

The facts listed below have been established.

In one case the same stock "seed" had been sown on two adjacent farms. The samples obtained from the resultant crops gave average germination percentages of 71 and 30 respectively. This difference must have been caused by the seeds having been produced or stored in the different environments.

There was little correlation between size of fruit and germination—small fruits did not necessarily contain poor seed.

There was a positive correlation ($r=0.42$, $P=0.02$) between the density of fruit and germination percentage. This was possibly related to the amount of stored food in the seeds, or to the presence of empty seed pockets in the fruits.

There was a positive correlation ($r=0.42$, $P=0.02$) between darkness of colour of the fruits and poor germination. The cause of the dark colour has not yet been investigated.

During germination tests there was more fungal growth on poor germinating samples than on good ones. This did not necessarily mean that the fungi were interfering with germination. Other work by the author has indicated that living seeds are not so readily attacked by fungi as dead ones.

In germination tests which involved burial for fourteen days in wet sand without air, a proportion of the seeds died.

*Beet "seeds" are from the botanical point of view "fruits" in each of which is embedded several seeds.

Continuous low temperature, just above freezing point, entirely prevented germination but did not kill the seeds.

In one case deterioration was found to have occurred between ripening in the field and marketing. Fruits from a hand-threshed advance sample gathered direct from the field gave average germination of 27 per cent. Fruits from the same crop after threshing and storage had a germination percentage of only 18. The fruits of the latter sample were darker in colour, less dense, and slightly larger than those of the advance sample.

Dr. P. de Kock (University of Aberdeen) (1) kindly examined some of the samples. He found no difference in amount of germination inhibitor present in good and bad samples. The author wishes to thank Dr. de Kock for undertaking this work.

SUMMARY

1. A series of experiments has been commenced to determine the nature of the cause of poor germination of some strains of Cheltenham Greenleaved beet.

2. Evidence has been collected which indicates that environmental conditions of seed production and storage may affect germination of the seed.

3. Positive correlations have been found between certain macroscopical characters of the fruits and germination of the seeds contained in them.

4. Germination tests under a variety of conditions have been carried out on a large number of good and bad samples of beet "seed" obtained from commercial sources.

5. The amount of germination inhibitor present in good and bad samples of fruits did not differ.

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ROTATION OF VEGETABLES WITH DIFFERENT MANURIAL TREATMENTS

By R. M. WOODMAN

As insufficient land was available for a replicated experiment to determine the effects of different manurial treatments on a rotation of vegetables, it was decided in 1934 to lay down plots with the various treatments in the form of demonstration plots on a light gravel soil at the Cambridge H.R.S., Huntingdon Road, Cambridge. In order to provide a demonstration at most times of the year with a rotation of vegetables, three plots were provided for each treatment so that the rotation could be entered simultaneously at three phases of the four-year rotation ; thus crops of at least three of the chosen rotation of five vegetables could be grown each year.

The rotation of vegetables used was Brussels sprouts, peas, summer lettuce, spring cabbage and carrots. The full number of manurial treatments for a factorial design could not be used and the following five treatments were chosen—NPK, NP, NK, PK and Nil where NPK represented the usual full manurial treatment of nitrogen (N), phosphorus (P) and potassium (K) for the particular vegetable. With three plots for each treatment to allow for the three phases of the rotation, there were thus fifteen plots in the block. The treatment plots were laid down in the above serial order of treatments, *i.e.*, without randomisation. The three plots for any treatment were considered, for the purpose of computing results, as being replicates of each other, although the particular vegetable for these three plots was grown in different years. Another block of fifteen plots was laid down adjacent to the above block. Here the treatments were identical with those of the first block except that every plot received dung (D) in addition to the fertiliser, *i.e.*, the treatments were NPK.D, NP.D, NK.D, PK.D and Nil.D.

With such a layout, it was appreciated that results obtained over a limited period of years might be of doubtful significance and might be permanently vitiated if the soil happened to be very variable. Nevertheless it appeared possible to arrive at a qualitative method of judging growth and yield results when a rotation of crops was grown over a period of years with a layout which was neither replicated nor randomised.

After a few years, it was noted that, in general, Brussels sprouts and peas appeared to be less responsive to variations in fertiliser treatment than lettuce or carrots. Lettuce and carrots, therefore, may be regarded as 'indicator' crops. Moreover, when a particular plot produced good growth for certain crops during two or three rotations but produced poor growth with other crops in the rotation, *i.e.*, preceding or following the former crops, it may be argued with some reason that this difference was caused by the fertiliser treatments and not by the fertility of the soil in the plot.

General notes on the effects of treatments up to and including 1946

Brussels Sprouts

Over a period of twelve years, Brussels Sprouts were found to be rather insensitive to dung or fertilisers. The overall effect of dung was to increase the yield of saleable sprouts for all fertiliser treatments and this was mainly brought about by an increase in the proportion of the early, selected (large) grade which is the most desirable market grade. Dung also increased the proportion of unsaleable sprouts (blowers, etc.). While dung encouraged early maturity, inorganic nitrogen delayed it, thus encouraging the production of late sprouts. The best total yield of selected grade was obtained from undunged plots with the omission of inorganic nitrogen (PK) ; a very low yield of the selected (large) grade resulted from the Nil treatment.

Pea

This crop was also found to be rather insensitive to dung and fertilisers. Dung did not show much overall effect with any of the fertiliser treatments, the greatest response being in combination with inorganic nitrogen. Dung induced early maturity to some extent and this accounted for any increase in total yield of marketable pods. Dung in the absence of all fertiliser treatment (Nil.D) gave the poorest yield. Maturity was retarded on undunged plots with potash omitted but was not retarded by the omission of inorganic nitrogen.

Summer Lettuce

Dung alone gave a slightly bigger yield of late lettuces. Inorganic nitrogen, phosphate and potash tended to bring about early maturity, while the complete fertiliser (NPK) gave equal yields of early and late lettuces. Dung added to any of the fertiliser treatments, increased the size and number of marketable lettuces ; it gave a higher yield of early lettuces than of late lettuces and increased the average weight per plant of early lettuces which, however, was less than that of late lettuces. Inorganic nitrogen tended to increase the size of both early and late lettuces. Omission of potash and/or phosphate (NP, NK or Nil) gave early lettuces with a higher average weight per plant than that for late lettuces. Omission of potash caused reddish-brown scorch of the leaves of mature plants ; without dung, it did not produce much scorch owing to the immaturity of the plants. There was no obvious connection between rainfall and yield.

Spring Cabbage

With all the fertiliser treatments, dung increased the total yield by weight and this was the result of an increase in the average size and in the number of marketable cabbages. These effects applied to both early and late heads and, in addition, dung hastened maturity. The complete fertiliser (NPK) was about equivalent in its effect on yield to a dressing of dung (Nil.D) or to dung with potash and phosphate (PK.D).

Inorganic nitrogen, even with dung, encouraged early maturity ; with or without dung it increased the yield and had an important effect on the yield and size of late cabbages. Potash, in the absence of dung, was necessary for a good yield as measured by number of plants but it had little effect on the number of late cabbages. Phosphate, like potash, was more important for early cabbages than for late cabbages.

Progressive decreases in the yield of early cabbages were brought about by the omission of potash, phosphate, nitrogen and of complete fertiliser, in the presence of dung ; with no dung, the omission of phosphate, nitrogen, potash and all fertilisers (Nil) caused progressive decreases in that order. Complete fertiliser (NPK) gave quite a good yield of early cabbages, while absence of fertilisers and dung (Nil) gave a very poor yield of early cabbages and a poor yield of late cabbages.

Unlike, lettuce, the average size of the late heads was greater than that of early ones with every treatment. Rainfall and yield were apparently unconnected.

Carrot

In general, dung depressed yields and inorganic nitrogen tended to have a similar effect. The absence of dung and of fertilisers (Nil) also gave low yields consistently. The best yields were obtained from plots with potash, phosphate and no dung (PK). Omission of phosphate and especially of potash depressed the yield but dung compensated for the omission of potash to some extent.

Top/root ratios were virtually constant on dunged plots and on undunged plots receiving potash. Continued omission of potash from undunged plots (NP and Nil) for about eight years, however, led to higher ratios. These abnormal ratios constitute

a deficiency sympton which has been observed by the author in carrots grown in a greenhouse either as cultures in the same light gravel soil as in these plots, or in a pure silica sand ; these other results have shown that the minimum concentration of potassium (as K) necessary for carrots in the soil solution, probably lies between 0.3 and 2.8 parts per million.

1949–50 Results

Crops of Brussels sprouts, peas, cabbage and carrots were grown on the plots during 1949-50 and the results are given below. It cannot be expected, of course, that these results for one year will agree closely with the above conclusions, which are based on results obtained during twelve years.

Grading of saleable sprouts was by sieve into *selected (extra small) grade*, 0.63–1in. (grade I in the table) ; *selected grade*, 1–1.25 in. (grade II), *selected (large) grade*, greater than 1.25 in. (grade III).

Yields of sprouts in lb. per 1/100 acre plot

	Treatment									
	NPK.D	NP.D	NK.D	PK.D	Nil.D	NPK	NP	NK	PK	Nil
All saleable ...	51.4	55.8	61.0	59.4	55.9	50.0	13.3	49.9	40.1	30.9
Early saleable ...	38.8	45.4	49.2	46.2	43.3	39.4	8.8	37.8	28.1	20.2
Late saleable ...	12.6	10.4	11.8	13.2	12.6	10.6	4.6	12.2	12.0	10.7
All Grade I ...	2.2	2.0	2.7	2.9	3.9	3.9	2.7	4.0	5.3	4.0
Early Grade I ...	0.2	0.1	0.9	0.7	1.4	1.6	1.1	2.0	2.3	1.1
Late Grade I ...	2.0	1.9	1.8	2.2	2.5	2.2	1.6	2.0	3.0	2.9
All Grade II ...	16.6	15.8	19.4	20.6	19.9	18.2	4.9	21.4	16.2	13.4
Early Grade II ...	9.2	10.0	12.3	15.3	13.3	13.1	4.1	14.0	9.9	7.8
Late Grade II ...	7.4	5.8	7.1	7.2	6.6	5.1	0.8	7.4	6.4	5.7
All Grade III ...	32.6	38.0	38.9	35.9	32.0	28.0	5.8	24.5	18.5	13.4
Early Grade III ...	29.4	35.2	36.0	32.2	28.6	24.8	3.6	21.8	15.9	11.4
Late Grade III ...	3.2	2.8	2.9	3.8	3.4	3.2	2.2	2.8	2.6	2.1
All unsaleable ...	18.9	23.5	20.8	15.0	13.3	16.2	6.6	11.3	11.5	5.6
Early unsaleable	15.3	19.4	17.2	12.9	11.1	14.1	14.2	9.0	9.5	3.4
Late unsaleable ...	3.6	4.1	3.6	2.1	2.2	2.1	2.4	2.3	2.0	2.2

Yields of peas in lb. per 1/100 acre plot

	Treatment									
	NPK.D	NP.D	NK.D	PK.D	Nil.D	NPK	NP	NK	PK	Nil
Total marketable	120.5	89.0	104.8	91.8	79.8	87.0	70.8	84.8	89.2	63.8
Early marketable	55.0	61.0	66.5	75.5	68.5	53.0	49.0	67.0	75.0	46.5
Late marketable	65.5	28.0	38.2	16.2	11.2	34.0	21.8	17.8	14.2	17.2

Yields of cabbage in lb. per 1/100 acre plot

	Treatment									
	NPK.D	NP.D	NK.D	PK.D	Nil.D	NPK	NP	NK	PK	Nil
Total weight of marketable heads	17.1	24.1	5.9	3.9	11.7	63.4	4.8	23.9	15.4	nil
Wt. of marketable early heads ...	8.0	15.3	1.0	3.1	3.6	31.0	nil	nil	0.6	nil
Wt. of marketable late heads ...	9.1	8.8	4.9	0.9	8.1	32.4	4.8	23.9	14.8	nil
Total wt. of marketable heads for 1949 ...	133.4	82.6	82.9	54.3	24.9	107.2	1.0	51.1	nil	nil

The cabbage yields for 1950 were the worst since the beginning of the experiment, the "take" on planting out being extremely bad. Results for 1949 are included in the table to show what is now considered as an "average" type of year.

Yields, etc., of carrots in lb. per 1/100 acre plot

	Treatment									
	NPK.D	NP.D	NK.D	PK.D	Nil.D	NPK	NP	NK	PK	Nil
Total yield of tops	74.0	73.8	72.8	70.0	59.8	63.0	50.0	68.0	53.5	18.2
Total yield of roots	172.5	198.5	189.5	222.5	207.3	179.5	75.0	167.3	195.8	37.5
Top/root ratio ...	0.429	0.372	0.384	0.315	0.288	0.351	0.667	0.407	0.273	0.468
Yield of ware ...	139.0	164.0	161.8	185.6	174.5	151.0	62.0	155.5	175.2	21.5
Yield of splits ...	21.5	12.5	14.0	16.8	18.0	20.8	2.0	4.0	12.5	nil
Yield of chumps, smalls, etc. ...	12.0	22.0	13.8	20.2	14.8	7.8	11.0	10.8	8.0	16.0

The yield from the PK treatment without dung and inorganic nitrogen was still good after sixteen years of this treatment, giving a total of 195.8 lb. of carrots (175.2 lb. of ware). The best yields were obtained from treatment PK.D, *i.e.*, without inorganic nitrogen 222.5 lb. total (185.6 lb. of ware). It has been pointed out already that a high top/root ratio produced by continued absence of potash and of dung was a deficiency sympton. This has been substantiated by the above results where the treatments NP and Nil have given high top/root ratios.

SUMMARY OF SAND-CULTURE EXPERIMENTS WITH VEGETABLES

By R. M. WOODMAN

A study of the nutrition of vegetables in sand and soil culture was begun in 1934 at Cambridge H.R.S. Most of the problems were studied in sand culture. Solutions containing the necessary nutritional elements were applied thus allowing comparison of the effects of three of the major elements, nitrogen, phosphorus and potassium on the growth, yield, bolting, etc., of different vegetables ; the effect of boron was also studied. One plant was used for each culture and the nutrient solution was applied at regular intervals in such volume (the same for each culture) as would cause flushing or drainage from the culture jar. A typical experiment would consist of replicated randomised blocks of six to eight treatments, each culture solution varying from a large number of parts per million of, say, nitrogen, to zero, other nutritional elements in the solutions being kept constant. This method which had to be used was less satisfactory than the $3 \times 3 \times 3$ lay-out used with soil cultures where nitrogen, phosphorus and potassium were varied simultaneously so that interactions could be determined.

The following is a summary of the findings of these experiments :—

Lettuce

Nitrogen deficiency brought about the development of anthocyanin pigments and finally etiolation ; sufficiency resulted in earlier hearting and favoured tops rather than roots (1).

Phosphate deficiency toughened the leaves and caused purple blotches on tinted varieties such as May King but not on the non-tinted variety Cheshunt Early Giant. Sufficiency of phosphate produced earlier and heavier heads (2).

Potash deficiency resulted in leaf scorch and reduction in size ; sufficiency did not induce early maturity (3).

Calcium deficiency decreased the yield, while magnesium deficiency gave the older leaves a bleached, whitish-pink appearance (4).

Soil cultures, using the same soil as in the field manurial trials (5), showed that the best yield responses were obtained with high nitrogen (6).

A study was made of the effect of time of sowing and of water supply on the growth and bolting of lettuce (7).

Turnip

Nitrogen, progressively diminished, led to progressive decreases in root yields. Early application of nitrogen, as sodium nitrate, was desirable for a high yield of roots ; post-seedling application gave a high yield of tops (8).

Progessive diminution of available phosphorus led to a continuous increase in yield until at and below a relatively low concentration (about 2-6 parts per million) there was a rapid decrease in yield. No adverse effects on the growth of the turnip were produced with fen soil at the highest concentrations of soluble phosphate owing to "fixation" of the phosphate (9) ; this was quite different from the behaviour with sand (10).

Potash deficiency caused grey-green scorch, limp foliage and leaf-drop, but a fairly low level of potash had to be reached (as with lettuce) before the yield was decreased seriously.

Absence of boron brought about wastage of foliage and ultimately death of the plant, the minute, rough-sided roots tending to rot ; 0.0681 p.p.m. of boron as borax gave apparently normal healthy plants (10).

Spring Cabbage

Nitrogen in diminished supplies delayed maturity and gave diminished yields ; excess caused severe marginal scorch.

Phosphorus in reduced quantities had little effect on maturity or yield until a low concentration was reached when there was a sudden decrease in yield.

Potassium deficiency caused severe marginal scorch, necrotic spots, leaf-drop and immaturity.

Absence of boron gave sickly, meagre-looking, amber green plants with narrow leaves, young leaf buds which turned brown and rotted, necrotic tissue on, and longitudinal cracking of the upper side of leaf petioles, and young leaves which tended to curl and ball-up (11).

Spinach

Nitrogen in quantities above 25 p.p.m. seemed unnecessary for optimum yield but larger amounts gave a good dark leaf colour and tended to retard flowering.

Phosphorus when reduced to 5.5 p.p.m. gave the optimum yield but further reduction decreased the yield (12).

Potassium deficiency caused plants to be small and produced scorch, limpness and death of the leaves ; potassium enhanced leaf yield.

Lack of boron resulted in small plants on which buds and new leaves died.

Carrot

A moderate quantity of nitrogen gave optimum growth of root. Application of nitrogen to a black fen soil, however, tended to decrease the yield (13).

Phosphorus deficiency caused bronzing of the foliage but a moderate amount of available phosphorus gave optimum root growth. Carrots of Chantenay type on a black fen soil deficient in phosphate had bronzed cotyledons and sometimes had bronzed foliage. The yield was increased following the application of phosphate.

Potassium deficiency caused serious scorch. With black fen soil, the application of potash tended to decrease the yield, whereas with gravel soil it produced a positive response in the roots and a negative response in the tops, *i.e.*, the top/root ratio for fresh matter was large with a deficiency of potash (14). This was confirmed by field trials on the same gravel soil (5) and by sand cultures of Primo carrots.

Absence of boron gave small, immature plants.

Carrots did not respond to fertiliser on land in very good heart but gave over 110 per cent. increase in yield of ware carrots with six inches of water applied by overhead irrigation (15).

The incidence of carrot fly possibly depended largely on the state of nutrition of the carrots (16, 17).

Onion

Nitrogen deficiency gave very pale green tops (17). The best concentrations of nitrogen in sand cultures lay between 16 and 33 p.p.m. (18).

Radish

Nitrogen deficiency produced a characteristic outlining in red of the cotyledons and red petioles, and led to poor growth (17, 19).

Available phosphorus was necessary to the extent of only 2-4 p.p.m. and as little as 0.1 p.p.m. gave marketable roots (19).

Potash deficiency led to serious scorch (19) and both potash and nitrogen were needed in moderately large quantities for optimum root development.

Pea

Small quantities of nitrogen and only moderate amounts of phosphorus and potassium were necessary for optimum growth. Potassium deficiency led to marginal scorch followed by general scorch and death of foliage. Absence of boron did not have much effect (20).

Cauliflower (Potash Nutrition)

The effects of varying amounts of potassium in nutrient solutions on the growth of cauliflower (Sutton's Harbinger) in pure sand in a glasshouse, were studied in 1950. One nutrient solution contained no boron.

There were eight treatments—A, 50.49 p.p.m. of potassium, B, 33.66 p.p.m., C, 33.66 p.p.m. with no boron, D, 22.44 p.p.m., E, 11.22 p.p.m., F, 5.61 p.p.m., G, 2.81 p.p.m., and H, 0 p.p.m. The lay-out consisted of ten randomised blocks of the eight treatments with one plant per treatment per block.

Seed was sown on 24th April ; germination had occurred by 5th May and plants were singled to one per pot on 12th May. During the experiment, each culture received 21.4 litres of its particular nutrient solution in lots of 350 or 400 c.c. at a time.

The following observations were made on the plants :—

30th May	A–F	Healthy plants.
	G	Smaller plants, lighter green in colour.
	H	Very small plants, almost yellowish-green.
27th June	A–F	Healthy plants.
	G	Smaller plants, lighter green colour with traces of marginal scorch.
	H	Very small plants, severely scorched, with leaves dying off and new growth very slow and almost blue-green in colour.
11th July	A–F	Curds forming and marginal scorch on five of the F cultures.
	G	Smaller curds forming and older leaves dying from scorch.
	H	Same as on 27th June.
25th July	A	Two curds rusty coloured.
	C	Two curds rusty coloured and one plant going "blind."
	E	One curd rusty coloured, marginal scorch of the central leaves of the plants.
	F	Three curds rusty coloured, marginal scorch of the central leaves of the plants.
	G	Scorch less noticeable as new growth appeared.
	H	One curd rusty coloured, plants unchanged in size and appearance.
10th August	—	Harvested.

W=White. B=Brown.
SB=Slightly brown. R=Rotted.

	Curd appearance							Other observations
	W	SB	B	R	bolting	blind	no curds	
A	2	5	1	1		1		
B	8	2						
C	4	1	1	2	1	1		
D	10							Curd appearance best of all treatments.
E	2	3	4	1				8 had marginal scorch of central leaves.
F	2	1	1		6			All had marginal scorch.
G	4				1		5	All had marginal scorch and were light green.
H							10	All small, purply-green plants with scorched dead leaves.

The following table shows the mean fresh weight and dry weight of different parts of the plants together with related data for the different treatments.

Cauliflowers. Treatment means in grams

	Treatment								S. E.
	A	B	C	D	E	F	G	H	
Fresh weight									
Plants	185.8	206.0	184.1	196.9	200.7	139.0	43.1	0.67	±8.35 (*a*)
Whole tops ...	174.8	195.7	175.1	183.0	188.1	130.5	40.7	0.60	±8.05 (*a*)
Roots	11.0	10.4	9.0	13.9	12.6	8.6	2.4	0.07	±0.92 (*a*)
Curds	24.0	37.1	22.4	30.8	26.1	20.4	3.3	0.00	±5.318(*a*)
Whole top/root ...	16.3	19.8	20.6	13.9	15.6	15.7	20.7	9.8	±1.61 (*c*)
Curd/whole plant ...	0.125	0.178	0.116	0.151	0.130	0.149	0.067	—	±0.026(*c*)
Dry weight									
Plants	26.0	28.4	24.8	27.9	27.3	14.1	4.0	0.17	±4.38 (*a*)
Whole tops ...	23.3	25.5	22.5	24.3	23.5	11.9	3.4	0.15	±3.91 (*a*)
Roots	2.73	2.89	2.38	3.64	3.80	2.18	0.58	0.02	±0.307(*a*)
Curds	2.76	4.02	2.62	3.16	2.96	2.26	0.30	0.00	±0.562(*a*)
Whole top/root ...	8.74	9.38	9.97	7.21	6.66	5.55	7.09	6.43	±0.831(*c*)
Curd/whole plant ...	0.106	0.164	0.106	0.120	0.108	0.173	0.091	—	±0.033(*b*)
% moisture									
Whole plants ...	85.8	86.2	86.5	85.6	86.4	89.9	90.8	72.6	±1.15 (*c*)
Whole tops ...	86.5	87.0	87.1	86.5	87.5	90.9	91.7	73.9	±1.18 (*c*)
Roots	74.8	72.0	73.8	74.2	70.2	74.3	75.9	59.1	±2.23 (*c*)
Curds	79.5	89.3	78.9	89.4	88.7	88.6	44.8	—	±5.17 (*a*)

(*a*) S.E. applicable to treatments A–F ; (*b*) S.E. applicable to treatments A–G
(*c*) S.E. applicable to all treatments.

Before discussing the results, attention must be drawn to the fact that the growth of cauliflower under the conditions of this experiment, namely, with nutrient solutions added to sand and in a glasshouse, was much inferior to the normal growth of cauliflower in soil in the open. The results from this experiment, therefore, may not be applicable to cauliflower grown in the ordinary way.

Treatments B and D with 33.66 and 22.44 p.p.m. of potassium respectively, gave the best yield of curds, by fresh weight and by dry weight, and the whitest curds. The yield of curds decreased as the quantities of potassium were decreased below 22.44 p.p.m. until no curds were obtained with no potassium. Absence of potassium greatly decreased the (whole top/root) ratio of fresh weights. Deficiency, 2.81 p.p.m., decreased the percentage moisture in the curds and decreased the (curd/whole plant) ratio for both fresh and dry weights.

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WATERCRESS INVESTIGATIONS

By D. M. SPENCER

Accounts of the preparation of watercress beds and of the cultivation of cress have appeared in two publications of the Ministry of Agriculture (1), (2). Types of watercress common in Great Britain have been described by Howard (3). Only two types are in general cultivation, the popular brown-leaved variety (a sterile triploid) and a green-leaved variety (a fertile diploid) which is rather more vigorous. In recent years there have been failures of the crop in various parts of the country, particularly in Hampshire and, in consequence, the present investigations were started.

There are few published records of diseases in watercress. Ainsworth (4) recorded Cucumber Virus 1. J. Johnson, as having caused Mosaic Virus Disease in Hertfordshire. Smith (5) referred to a disease which followed infection by Cucumber Yellow Mottle Mosaic and also cited Cheo as attributing considerable losses to Cabbage Black Ringspot Virus (6). W. C. Moore (7) noted that *Pythium* sp. had been associated with stem and root rot in Kent in 1937 and 1938 and that Cucumber Mosaic virus had been recorded in Hertfordshire (1935), South Wales (1935) and Hampshire (1939).

There is little information also on damage by insects and similar pests although some attention has been paid to this aspect by the Entomology Department of the N.A.A.S. at Reading. Lyon at Cambridge has studied the physiology and nutrition of watercress but his results have not yet been published.

SURVEY OF BEDS

A survey of watercress beds in Hampshire and other home counties was made in order to ascertain the nature of the problems and to study cultural practices. The survey showed that weeds, algae, mineral deficiencies, pests and probably diseases due to fungal or virus infection all reduced the crop to a greater or lesser extent.

Weeds

The main weeds seen were as follows :

Callitriche aquatica. This is known variously as Starweed, Starwort or Silkweed. Sometimes it is very abundant and causes loss by entangling large patches of watercress so that harvesting is impossible.

Lemna spp., Duckweed, floats on the surface of the water and adheres to the watercress. It can be troublesome but in properly constructed beds it can be removed by raising the water level and pushing down the plants so that the weed is floated off.

Glyceria aquatica, Reed Sweet Grass, occurs in some beds and is difficult to remove.

Apium nodiflorum is to be seen in most beds. It is not difficult to uproot but is commonly mistaken for watercress by inexperienced growers.

Algae

Species of *Ulothrix* and *Spirogyra* often form a scum on the water surface and the watercress becomes entangled in this.

Cladophora forms a thick mat on the floor of the bed and is commonly known as "flannel weed."

Virus Diseases

References to virus diseases of watercress have been made above. Cheo, at

Cambridge, found that plants from some beds were infected by one or more strains of Cabbage Ringspot virus, but did not publish his conclusions as to the injury caused. In the present investigation, symptoms agreeing with those described by Cheo were seen but there was no evidence that infection was followed by loss of crop.

Fungal Infections

Various fungi, including *Pythium* sp., were found on dead or dying watercress. The only fungus or fungi, however, which were likely to have been associated with crop failures were those present in distorted roots. These apparently belonged to the *Plasmodiophorales* and were presumably identical with those noted by Webb (in correspondence) and Osterberg (unpub.). Work with these root fungi is described below.

The Main Disorder

The survey of beds began in October, 1949, but it was not until the third week of the month that any of the beds visited showed the first signs that death of plants might occur. Further, growers agreed that the symptoms were rarely marked until early January. During the winter, the writer kept 48 beds under observation and partial or complete failures were found in most of them during the months of January, February and March. As a rule, the first plants to be affected were at the lower end of the bed, that is, remote from the source of water.

The same sequence of symptoms, described below, was associated with all the failures ; it was concluded from this that the same agent was responsible in all cases. The first indication that a plant was affected was a chlorosis of the young leaflets which finally became yellow. These did not develop to full size and, in a few days, where the disorder progressed, the margins curled downwards and inwards. Within a few weeks from the first expression of the symptoms, the underwater part of the stem usually became moribund and the lower leaves withered so that when viewed from above, the whorl of young distorted leaflets formed an octagonal rosette at the apex of each stem. In extreme instances, the stalks became completely rotten and lost anchorage of the roots so that they floated away in the water current. Accompanying the foliar symptoms, changes in root shape occurred. A healthy plant possessed at each underwater node about six to twelve primary roots, 2 to 4 inches in length. From each of these grew numerous rootlets 0.5–0.75 inches in length. When an affected plant was examined in the autumn or winter, the primary roots were either absent or reduced in length and distorted. Typically, there was at each node only two or three roots each about 0.25 inches in length, with the secondary roots absent. These roots were swollen, curved and brittle. This peculiar distortion has been noted by growers and by other workers and has given rise to the names "crook root" or "curly root."

From about April onwards there was a recovery of those plants which had remained anchored. The new foliage became normal in colour and shape and new primary roots, 3 to 4 inches in length, were developed. As a rule, they were free from distortion though a small number were swollen near the tip. Secondary roots were also produced in profusion but showed symptoms of disorder. Instead of the white flexible rootlets, seen in healthy plants, they were creamy-brown in colour, brittle, swollen near the tip and rarely exceeding 0.25 inches in length.

Resistance

There was little doubt that the less vigorous brown-leaved type of watercress was less tolerant of the disorder than was the green-leaved type.

CROOK ROOT

The Fungus

Two distinct types of fungal body were found in the tissue of the distorted roots

and these agreed in appearance with the "zoosporangia" and "spore balls" as described by Webb (in correspondence) and considered by him to be two forms of a single species of the *Plasmodiophorales.*

Zoosporangia, unaccompanied by spore balls, were seen in abundance in the epidermal and cortical cells of roots of watercress collected in the first weeks of the investigation (October, 1949) and these filled hypertrophied cells in the manner of *Plasmodiophora.* Hyperplasia was also associated with infection. More critical examination of roots showed the various stages from the formation of plasmodia to zoosporangia.

Spore balls were not seen until June, 1950. They were first found in secondary rootlets and were accompanied by zoosporangia, the two fungal types being in different cells. As the summer advanced spore balls became more abundant, and were sometimes to be found in the absence of zoosporangia.

Germination Experiments

Deformed roots of diseased watercress from many sources were examined and although zoosporangia were frequently seen, only in a few cases did the absence of cell contents indicate that germination of the zoosporangia had already occurred. At no time were the contents of the cells of the spore balls found to be absent.

In order to find out whether germination could be induced by higher or lower temperatures than those of the laboratory (about 15° C.), roots containing zoosporangia and spore balls were placed in petri dishes containing distilled water. Some of these were incubated at 19° C., 23° C. and 25° C., while others were placed in a refrigerator at 3° C. Three days later, many of the zoosporangia at the higher temperatures were seen to have lost their cell contents and biciliate zoospores were abundant in the water. After about two weeks the zoosporangia had all disintegrated. With six weeks incubation there was no obvious change in the cell contents of the spore balls.

The material subjected to 3° C. showed no change after six weeks but this low temperature did not retard germination of zoosporangia when incubated subsequently at the higher temperatures.

Further experiments showed that germination of zoosporangia would occur within the range of pH 5.5–8.0.

Infection Experiments

(*a*) *In Cascades*

In order to ascertain the role of the fungus associated with the distorted roots, attempts were made to infect healthy roots. As it seemed unlikely that satisfactory preparations could be obtained in pure culture, experiments were set up using diseased roots as a source of the fungus. Infected plants taken from commercial beds were grown on in the laboratory by standing them in beakers of water (distilled or main). Under these conditions the infected roots tended to rot ; new healthy roots developed but the fungus was never seen in them during the few weeks the plants remained alive.

In order to keep the plants vigorous over long periods, and to increase the likelihood of success, it was decided to imitate, as nearly as possible, the conditions in a watercress bed. A cascade apparatus was set up with three aluminium trays at different levels. Water from the main supply was dripped into the top tray and the overflow passed through four tubes leading into funnels set in the tray below. The stem of each funnel reached to the bottom of the tray so that the flow towards the outlets was not on the surface alone. The lowest tray was fitted in a manner exactly similar to the middle tray. Cuttings of plants grew well in these cascade trays and thrived under laboratory conditions for at least 16 weeks.

Watercress with diseased roots containing both zoosporangia and spore balls was

placed into the top tray while healthy cress was placed in the trays beneath. After 14 days, no infection of the healthy roots could be detected and the diseased cress in the upper trays showed signs of recovery. It was concluded, therefore, that either the conditions were unsuitable for the zoosporangia to germinate, or that the conditions for infection were unsuitable.

Measurements made by Lyon (unpub.) have shown that water emerging from an artesian bore generally had a reaction of about pH 7 and that after losing carbon dioxide on passing down a bed, it was changed to pH 8. As the lower end of a bed was usually the first to be infected, it was thought that reaction might be a significant factor. Experiments were carried out, therefore, using the cascade apparatus, and main water with the reaction changed to pH 7.8. Water from the main had a reaction of pH 6.8 and it was found that by heating this water to about 30° C. as it passed through a glass flask, sufficient carbon dioxide gas was driven off to change the reaction to pH 7.8. The cascade apparatus was placed at a south-facing window in a laboratory and the sources of inoculum used were as follows :—

(1) Diseased roots.

(2) Mud, collected from the bottom of a bed which had borne infected cress, and placed in the top tray.

(3) Zoospores and germinating zoosporangia placed in the top tray.

(4) Diseased roots ; sunlight period reduced to eight hours and water temperature reduced to 5° C. or less.

(5) Zoosporangia in diseased root tissue, incubated and placed in the top tray of the cascade ; fresh supplies given at weekly intervals. Cascade placed outdoors.

In (4) an attempt was made to imitate winter conditions at the bottom end of a commercial bed. In (5) the plants were subjected to conditions of light and temperature similar to those in commercial beds.

Frequent microscopic examination was made of roots of plants in the trays but no infection was seen to have occurred with any of the above sources of inoculum.

(*b*) *In Soil*

Since the conditions in the cascade apparatus appeared to be unsuitable for infection of the roots by zoospores released from germinating zoosporangia, it was decided to experiment with plants growing in soil and gravel.

Healthy shoots about four inches in length were planted in six seed boxes as follows :—

1 box containing J.I. 1 compost at pH 8.

1 box containing J.I. 1 compost at pH 8 and infected roots well mixed with the medium.

1 box containing J.I. 1 compost at pH 5.4.

1 box containing J.I. 1 compost at pH 5.4 and infected roots well mixed with the medium.

1 box containing washed gravel.

1 box containing washed gravel and infected roots well mixed with the medium.

After three days in a glasshouse the plants had become established and the boxes were transferred to the laboratory. Subsequent growth of the plants was so vigorous in the four boxes containing compost that it was necessary to harvest at weekly intervals. Growth was also good but less vigorous in the gravel. After five weeks, the roots were examined microscopically but there was no evidence that infection had occurred.

DISCUSSION

The first year's investigation has focused attention on the fungal bodies (zoosporangia and spore balls) found in the distorted roots of diseased watercress, and it has been questioned whether these belong to the same or different species of the order *Plasmodiophorales;* it has been tentatively assumed that they are primarily responsible for the disorder with which they are associated. There is some published work on the details of the life histories of members of the *Plasmodiophorales* but interpretation of the various forms seen is still controversial.

The writer has noted the germination of zoosporangia but not of the spore balls. Infection of the roots of healthy watercress under laboratory conditions has not yet been achieved but special attention will be given to this.† Newly formed roots on healthy shoots which have been laid in commercial beds for less than three weeks, have exhibited typical distortion and infection. This has indicated that the environmental conditions of beds have not so far been imitated successfully in the laboratory and/or that the source of inoculum was unsuitable. Watercress is very easy to grow under laboratory conditions ; development of roots is indeed so vigorous that it may well be a factor checking infection.

Observations on commercial beds will be continued in order to trace the seasonal sequence of symptoms of the disorder.

SUMMARY

1. In autumn, 1949, a survey of commercial watercress beds was made to discover the cause or causes of recent crop failures.

2. It was found that reduction of yields was attributable to weeds, insects, nutritional disorders and possibly to a virus disease. The main cause of loss, however, was due to a single disorder which was present in nearly every bed visited.

3. The first obvious symptom was chlorosis of the foliage which became marked in early winter. This was accompanied by a distortion of the roots (crook root) and followed sometimes by death of the plant. Where plants survived, recovery began about April.

4. Two distinct fungal bodies (tentatively named zoosporangia and spore balls) belonging to either the same or different species of the order *Plasmodiophorales*, were associated with the distortion of the roots.

5. Germination of zoosporangia followed within three days of incubation of infected root tissues at a range of temperatures. Germination of spore balls has not been observed.

6. Using trays arranged in cascades, and running water, unsuccessful attempts were made to infect healthy roots.* The sources of inoculum used were (*a*) diseased roots ; (*b*) mud from an affected bed and (*c*) zoospores.

7. Unsuccessful attempts were made to infect roots of watercress growing in soil and in gravel.

Acknowledgment is made to Mr. H. H. Glasscock for valuable help and advice given at all stages of the work. Thanks are also due to Professor W. Brown, Mr. G. Samuel and Mr. A. G. Lyon for useful suggestions, and to the County and District Officers of the N.A.A.S. who accompanied the writer on visits to watercress beds.

*In April, 1951, infection of healthy plants was achieved under laboratory conditions.

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STATISTICS REPORT

By J. A. NELDER

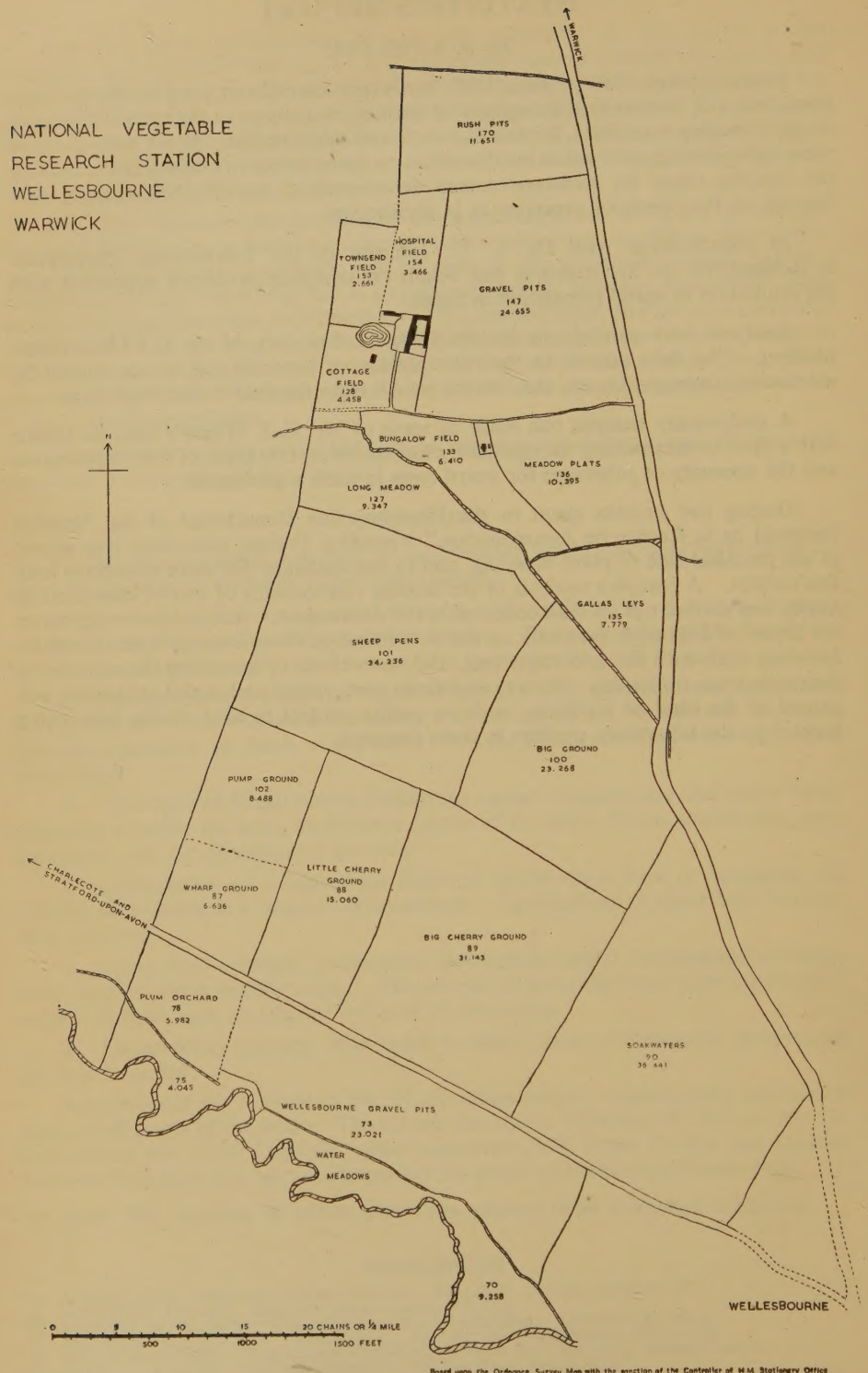
From October 1949 to June 1950, the writer carried out work in the Statistics Department of Rothamsted Experimental Station on analyses of field trials of various crops, including vegetables, for the N.A.A.S. and other bodies. Work arising out of these included an investigation into the effect on the accuracy of cereal trials in bulking the samples taken for moisture-content determination, and the collecting of data bearing on the design of experiments in glasshouses.

In collaboration with Dr. C. G. Johnson of the Entomology Department at Rothamsted, an investigation was begun on sampling problems connected with the estimation of aphid population in beans.

Analyses were carried out for the Ditton Laboratory of the D.S.I.R. at East Malling. The data related to the deterioration of broccoli and lettuce caused by mechanical damage, disease, etc., during transit from the field to the retail stage.

A preliminary analysis was made of some of Mr. E. J. Winter's data on lettuce with a view to determining the optimum plot size for certain types of field experiments and the necessity or otherwise for guard rows in these experiments.

During five months spent in the Plant-breeding Department of the "Institut National de la Recherche Agronomique," Versailles, France, experience was gained in the practical side of plant-breeding, and in the statistical problems connected with this subject. A complex analysis of the linkage relationships of several characters in barley was carried out on data collected in the department. Advice also was given on the layout of field trials generally, on the determination of optimum plot-size for plant-breeding trials with flax and sugar-beet, and on methods of increasing the accuracy in fungicide trials on apples. Several seed firms were visited and useful experience was gained of the kind of problems, such as quality control in seed, which were being tackled by the laboratory workers in these concerns.



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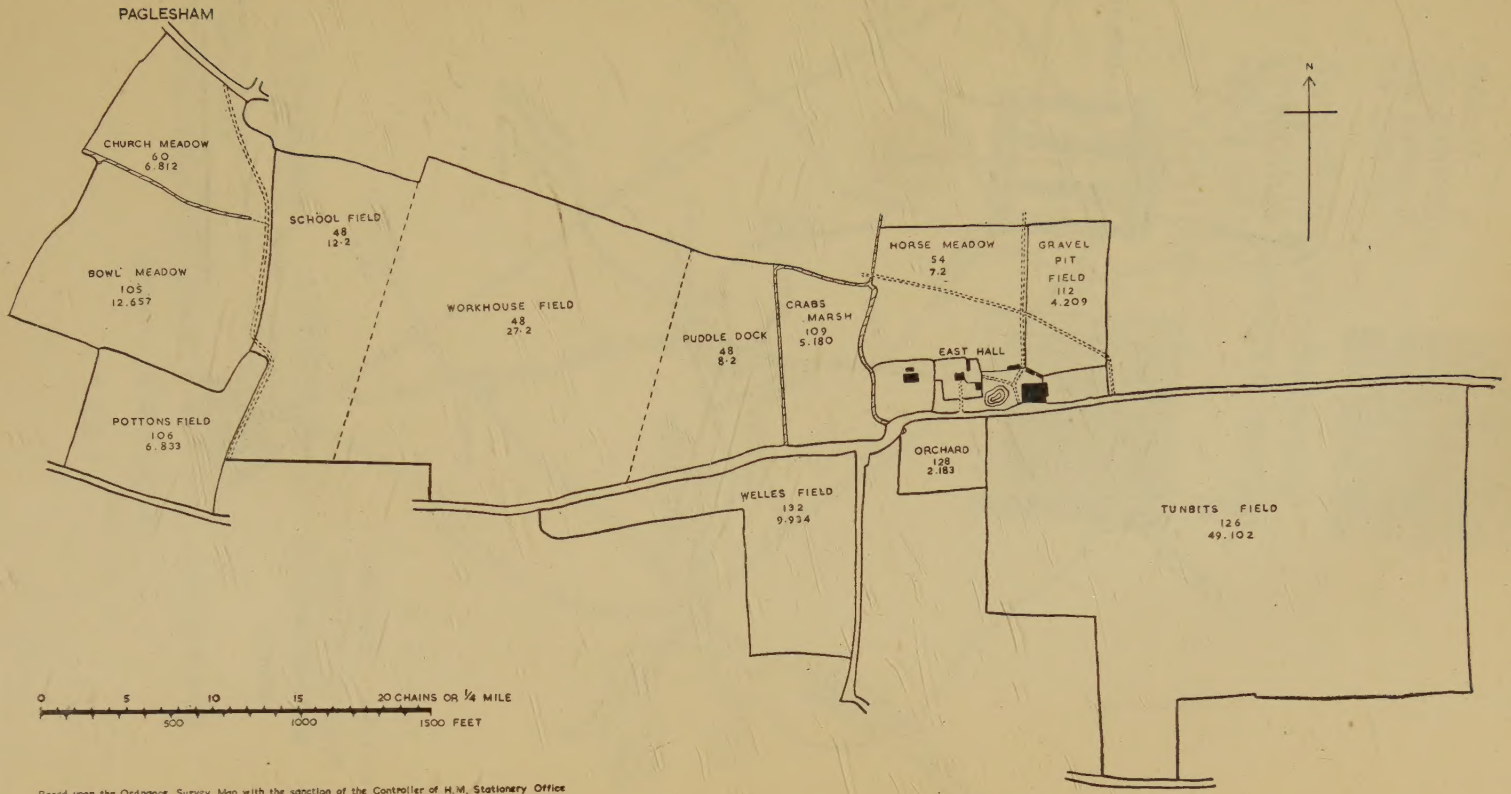

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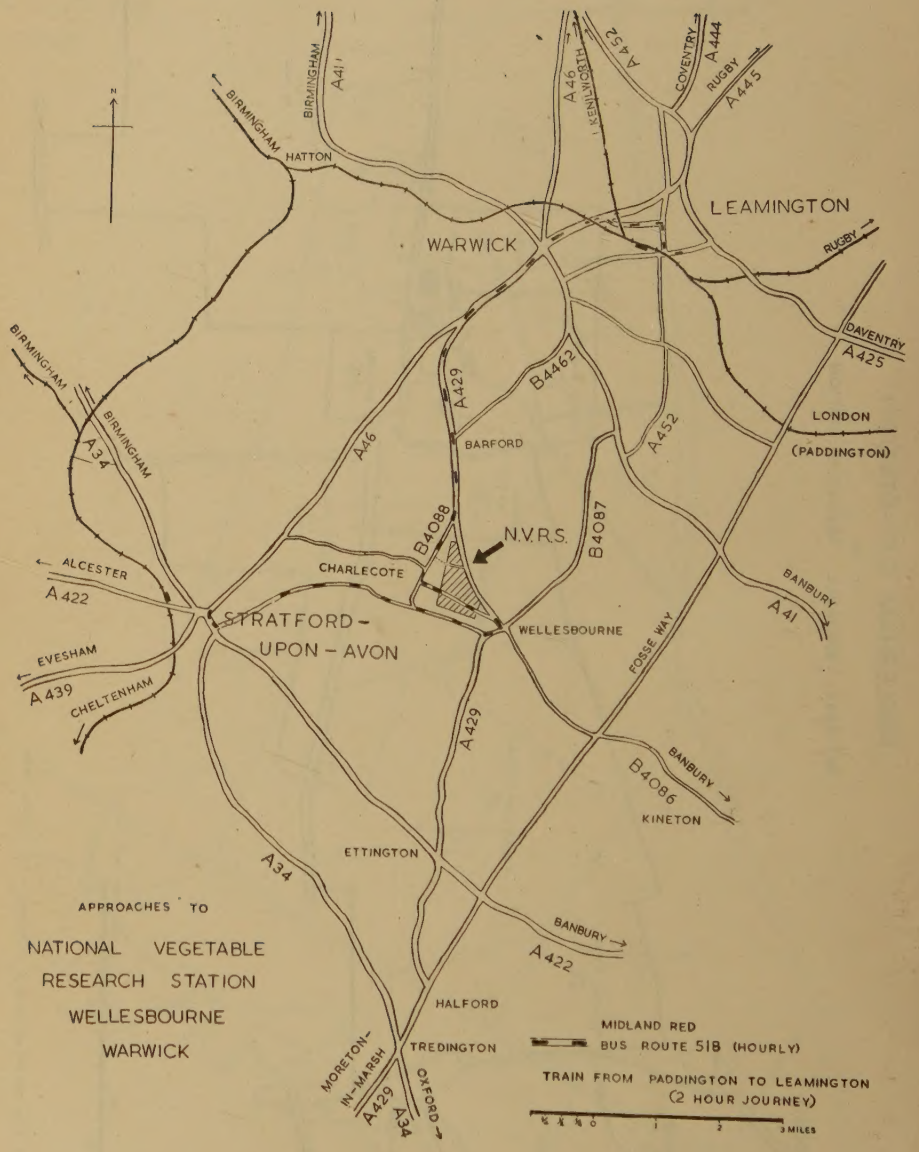

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